Procedure Handbook for Shipboard Thermal Sprayed Coating Applications

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in cooperation with

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San Diego, California

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Procedure Handbook
for
SHIPBOARD THERMAL SPRAYED COATING APPLICATIONS

March, 1992

prepared and submitted by:

National steel and shipbuilding Co.
San Diego, California

TASK NO. N3-89-1

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FOREWORD

This research project was produced for the National Shipbuilding Research Program as a cooperative cost-shared effort between the U.S. Navy and National Steel and Shipbuilding company (NASSCO). The Surface Preparation and Coatings Panel (SP-3) of SNAME'S Ship Production Committee sponsored the project under the technical direction of Lyn Haumschilt of NASSCO, NSRP Program Manager.

The handbook was prepared by NASSCO, with Les Hansen acting as Project Manager and primary author. Roger Snyder, NASSCO'S Thermal Spray Supervisor, served as Principal Investigator and contributed significantly to the project. Larry Suhl, President of Flame Spray, Inc. of San Diego, acted as Project Consultant and provided invaluable technical expertise, as well as co-authoring the handbook.

We thank the following Shipyards and their representatives for graciously conducting tours of their facilities and providing support and assistance

> Thomas Bourgeois and Roger Bohanan of Avondale Shipyards; Oren Funkhouser and Scott DeVinney of Bath Iron Works; Jim Freeman and John Evans of Ingalls Shipbuilding; and Jim Herbstritt of Puget Sound Naval Shipyard.

A draft of this report was provided to several members of the SP-3, Surface Preparation and Coatings, Panel for review and comment prior to publication. The report was also reviewed by representatives of NAVSEA Codes 07241 and 5141 (Corrosion Control), as well as a corrosion control consulting firm in San Diego.

All general overview comments were favorable and complimentary. Specific comments related to content or format were addressed and the resulting edits have been included in the published document.

The authors would like to thank the reviewers for their valuable time and effort. Additional comments on this published report or the overall project are welcome at any time, and they may be directed to the SP-3 Panel Chair or Program Manager.

1. INTRODUCTION

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Thermal spray application of aluminum or zinc coatings to a steel substrate is well established for long term corrosion protection. This superior protection has been documented for a wide range of commercial and military applications and in various environments, particularly in the severe marine environment. The U.S. Navy has been specifying the use of thermal sprayed (also known as metal sprayed or flame sprayed) coatings for new construction as well as overhaul and repair work since the late 1970s. To support these coating specifications, the Navy developed and published DoD-STD-2138 (SH) - "Metal Sprayed Coating Systems for Corrosion Protection Aboard Naval Ships" - in 1981. All Navy contractors me required to comply with this document, which outlines stringent procedures for surface preparation and coating application, certification of facilities and operators, production, quality assurance, testing and record keeping. Therefore, any shipyard or contractor that is faced with providing thermal spray services to the Navy should be knowledgeable of all aspects of this DoD Standard.

Thermal spray, although a coating process, is significantly different from conventional painting. Due to the specialized equipment requirements and the relatively low production rates inherent in the thermal spray process, application costs per item or area are usually high, particularly compared to painting. Life-cycle costs however, can be significantly lower for thermal sprayed coatings when compared to painting (Ref. 1). Thermal spray application costs can vary significantly depending on the location or environment of the application (shop vs. shipboard).

Shipyards with Navy contracts requiring thermal spray must decide whether to set up an in-house facility and training program, or subcontract the work to a qualified subcontractor. Most shipyards choose the former alternative to better control cost and schedules, and avoid problems associated with integrating a subcontractor into the busy on-board outfitting construction phase. However, there may be situations where subcontracting is a more cost effective alternative.

Due to unfamiliarity with the processes involved, shipyards new to thermal spray often lack the detailed cost and background information required to perform an adequate make-or-buy (subcontract) analysis. Conversely, shipyards with established thermal spray programs may not possess an adequate documentation trail to enable the periodic review and evaluation necessary to fine-tune their methods and operations.

2. OBJECTIVES

The principal objective of this project is to produce a handbook for thermal spray coating applications. The purpose of the handbook is to provide guidance and assistance to shipyards from two points of view. First, the handbook is intended to guide a shipyard that is preparing to establish a thermal spray program for the first time in accordance with current U.S. Navy requirements. The second objective is to assist shipyards that are currently involved in an active thermal spray program by providing information and data that can be used to analyze and reassess their current methods, thus leading to potential improvements or cost savings.

Since most major shipyards today have established thermal spray facilities to support U.S. Navy contracts, the latter objective will likely be more relevant to the users of this handbook. Significant atten-

tion will therefore be placed on making this document useful to those shipyards. In addition, it is the authors' desire that the handbook become a "hands-on," practical tool to benefit the wide range of personnel involved in the thermal spray arena, particularly planners, estimators, engineers, production supervisors and shop managers. The handbook's format and style have been designed with this in mind.

3. **PROJECT OVERVIEW**

To support the project objectives as discussed in Section 2, this handbook outlines the theory and application of thermal sprayed aluminum (TSA) coatings as well as describing facility requirements, training programs, equipment and application costs, quality, safety and environmental issues. In addition, Section 10 describes and summarizes the key elements necessary to implement a shipyard thermal spray program.

Although aluminum, zinc and various alloys are used successfully in the thermal spray process, this handbook addresses aluminium coatings only, since this coating is currently being specified by the U.S. Navy for shipboard corrosion control. Also, all information presented herein supports the requirements of the currently approved government standard for thermal spray, DoD-STD 2138. Some information is presented in the form of direct quotes from the standard, and the complete standard is included as Appendix H. It should be noted that at the time of this writing a revision to 2138 is nearly completed and expected to be issued by the Navy early in 1992 (2138-A). This handbook makes several references to updated information contained in the draft version of 2138-A.

The research for this project was accomplished in several phases as Summarized below

- Conduct shipyard and subcontractor surveys related to methods, production rates and equipment. (Survey results are summarized in Appendix A.)
- Identify and analyze current methods of thermal spray applications and related equipment usage.
- Compile production rate data for various types of thermal spray applications.
- Perform an industrial engineering study to determine overall costs per unit area.
- Outline requirements and procedures leading to certification in accordance with DoD-STD 2138.
- Assemble all data and information to create the thermal spray handbook

Also, visits were made to the following shipyards to tour thermal spray facilities and discuss the project surveys:

- Avondale Shipyards, New Orleans, LA.
- Bath Iron Works, Bath, ME.
- Ingalls Shipbuilding, Pascagoula, MI.
- Puget Sound NSY, Bremmerton, WA.
- SIMA, Naval Station, San Diego, CA.

4. INTRODUCTION TO THE THERMAL SPRAY PROCESS

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4.1 Definition of Thermal Spraying

Thermal Spraying is a group of processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semi-molten condition on a prepared substrate to create a spray deposit. The material used may be in the form of powder or wire. The thermal spraying gun generates the necessary heat by using combustible gases or an electric arc. As the materials are heated they change to a plastic or molten state and are accelerated by a compressed gas. The confined stream of particles is conveyed to the substrate. The particles strike the surface, flatten and form thin platelets (splats) that conform and adhere to the irregularities of the prepared surface and to each other. As the sprayed particles impinge upon the substrate, they cool and build up, particle by particle, into a lamellar structure, thus a coating is formed (see Fig. 4.1).

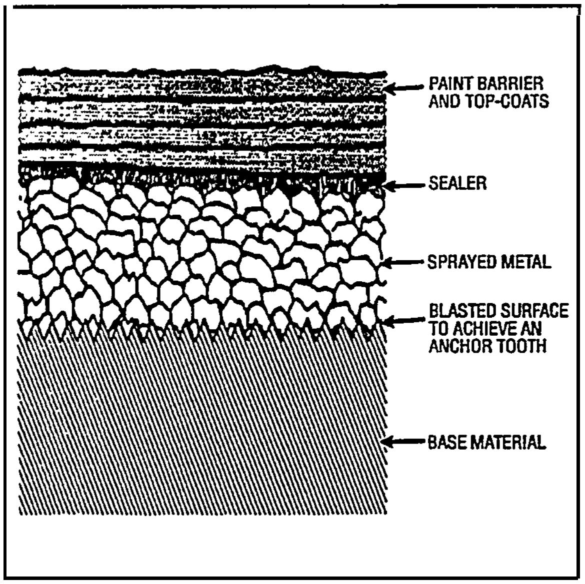
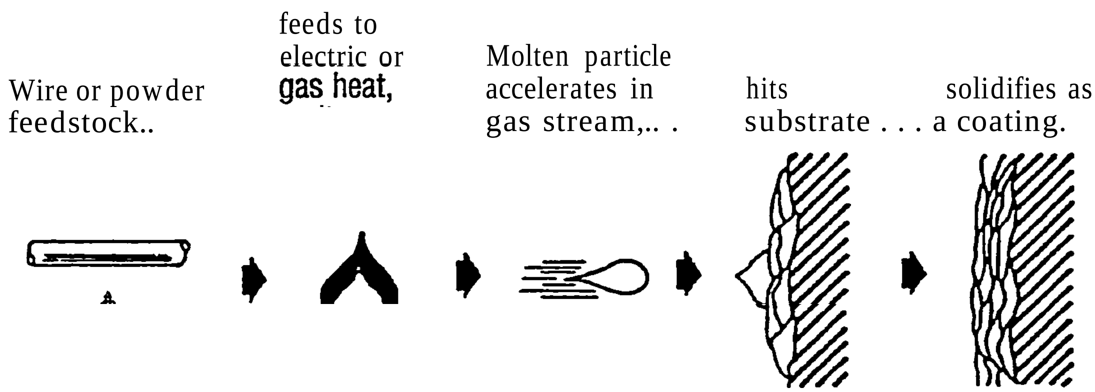


Fig. 4.1 ***Typical Coating Cross Section***

The commercial use of thermal spraying covers many applications such as: restoration of dimension, hard facing, electrical conductivity, electrical resistance, wear resistance, thermal barriers, Radio Frequency Interference (RFI) or Electro-magnetic Interference (EMI) shielding and corrosion protection to a variety of components. It is important to note that there is a wide utilization of thermal spray coatings for applications in nearly all industries. Thermal spraying is a time-proven process that when properly applied and engineered provides a surface treatment which can greatly enhance the serviceable life of components.

HOW THERMAL SPRAY COATING WORKS



4.2 History of TSA Coatings for Corrosion Protection

Most U.S. shipyards are currently, or soon will be using thermal sprayed aluminum (TSA) coatings to provide corrosion control of various components for the U.S. Navy. Following is an overview of where TSA coatings are currently being applied in industry. This information is important background that shows the acceptance of these coatings throughout all types of industries for corrosion protection.

Thermal sprayed coatings are used for protection of iron and steel in a range of corrosive environments. Long-term effectiveness (twenty years) in both industrial and marine locations has been documented (Ref. 2). The two most commonly used processes to apply these coatings are Combustion Flame Spraying and Electric Arc Spraying. Flame and arc spraying give rapid, uniform coverage at economical spray rates, and are replacing conventional paint primers for many corrosion applications. The natural surface texture of these coatings provides an excellent base for sealers or paint top coats.

Zinc and aluminum coatings provide the broadest atmospheric protection, and the choice in their use is often based on the relative ease of application and comparative costs for the specific case. These coatings are more corrosion resistant than steel, and hence form an effective atmospheric barrier. Zinc and aluminum are anodic to steel. They also protect the ferrous substrate in electrolytic solutions. The coating serves as a sacrificial anode and is consumed over time. This reserve cathodic protection acts to prevent corrosion of the substrate even when the coating coverage is incomplete or suffers mechanical damage.

Aluminum corrodes less rapidly than zinc in highly acidic conditions, while zinc performs better than aluminum in alkaline conditions. Aluminum and zinc coatings both have good adhesion to grit-blasted steel. Because thermal spraying does not cause excessive heating of the substrate, there is no effect on the mechanical properties of the substrate.

There is a history of corrosion protection by thermal spraying for structural steel work. Included are buildings, bridges, towers, radio and TV antenna masts, steel gantry structures, high power search radar aerials, overhead walkways, railroad overhead line support columns, electrification masts, tower cranes, traffic island posts, and street and bridge railings. Wellhead assemblies for offshore use have been coated for salt atmosphere corrosion protection since the 1950s. The process has been used for flare stacks, refinery columns, and for external protection of oil and propane gas storage tanks.

The interiors of fluid cargo rail cars are thermal sprayed to control fluid purity and guard against iron contamination. Steel railroad cars are zinc sprayed for corrosion protection. These coatings should last the lifetime of the cars, thus eliminating the need of removal from service for painting (approximately every five years). Spraying has been used to protect pipelines against many types of environments. Lengths up to forty feet (12m) have been successfully coated internally. Pipe couplings, manhole covers, and other small industrial items are also coated.

In marine applications, hulls, deck sections, and portions of barge, scow, tug, and fishing vessel superstructures have been sprayed with excellent long term results. Lifeboats and floating caissons have also been coated, as well as smaller items ***such*** as ship rudders and the axles of boat trailers. A common usage of metal spray is on piers, pilings, and ferry berths.

4.3 U.S. Navy's Use of Thermal Sprayed Coatings

The Navy uses sprayed aluminum for corrosion control to obtain a reduction in ship's force maintenance man-hours. Today, Navy ships have more highly trained sailors performing planned maintenance. Less time is available for maintenance problems due to corrosion. The use of aluminum sprayed coatings for corrosion control is intended to minimize the need for corrosion maintenance painting over the service life of the component.

The U.S. Navy's use of aluminum sprayed coating systems began in 1977 when initial tests were carried out on high temperature steam valves. It quickly became apparent that aluminum sprayed coating systems were providing long-term protection to the steam valves and significantly reducing preservation maintenance man-hours. The original steam valves coated in 1977-1978 are still under evaluation and no recoating has yet been required. The success of these original applications has spawned many more applications on Navy structures and equipment in corrosion-prone areas.

The Navy foresaw that significant benefits would be gained by standardizing the application process for aluminum sprayed coating systems so it developed and issued DoD-STD-2138, "Metal Sprayed Coating Systems for Corrosion Protection Aboard Naval Ships" (dated 23 November 1981). This document provides guidance covering materials, equipment, processes, examination, and personnel qualification for applications of aluminum sprayed coating systems for corrosion control.

DoD-STD-2138 was developed from the best information available within the maintenance community; it relied heavily on technology transferred from Naval laboratories and shipyards, private industry, and technical societies such as the American Society for Metals, American Welding Society, and the Steel Structures Painting CounciI. The development goal was to provide a workable standard of guidance (according to good commercial practice) for aluminum sprayed coating system applications. The DoD Standard concentrates on the critical parameters (surface preparation, for example) of the coating process. The advice of commercial applicators was sought to ensure a usable document that would provide guidance as well as direction in achieving a high quality coating system.

A revision to the 1981 issue of DoD-STD 2138 is expected to be published by mid-1992. The new issue has incorporated the lessons learned over the last ten years, and it shows the U.S. Navy's commitment to this technology by continuing to incorporate new and improved methods of application and control.

The key points of DoD-STD-2138 are process standardization and the importance of metal sprayed coating "systems." By developing and implementing this Standard, the Navy is attempting to ensure that each activity, government (Navy) or private, is providing the same high quality coating system.

The requirements of the DoD Standard limit the range of the variables in the process. A surface coated in accordance with DoD-STD-2138 receives surface preparation, coating application, and sealing that reflect recognizable standards. This benefits the Navy by providing a proven product and benefits the contractor by reducing operator errors that lead to failures. In addition, the use of a proven process ensures a long-life coating and fosters early detection of process problems.

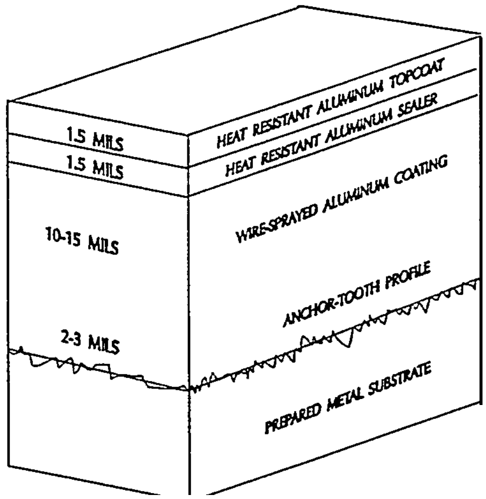


Fig. 4.2 Type I System for High Temperature Applications

One example of process problems is found with surface preparation requirements. The Standard requires a white metal surface with an anchor tooth pattern of 2-3 mils. This is measured with a press-o-film profile tape. The steel surface is required to be completely thermal sprayed within six hours of surface preparation. When the correct anchor tooth pattern is not achieved or the steel surface is allowed to remain uncoated longer than six hours, lower bond strengths are obtained. This can result in coating failure in less than one year.

A thermal sprayed aluminum (TSA) coating applied in accordance with DoD-STD 2138 will have a non-through porosity thickness of about seven roils and a tensile strength greater than 2000 psi. Seven roils will give barrier protection and anodically protect the substrate if the coating is damaged, exposing the base material to the environment. Additionally, a seal coat is always applied to a TSA coating to improve the barrier and provide a tie coat for subsequent paint coats. The Navy's TSA coating system is essentially a metallized primer topped with the designated top coat paint system. The TSA component is the long-lived component, and the five-coat paint component is renewed as required by "wear and tear" of the shipboard traffic and the marine environment. TSA coatings can provide effective long-term (over ten years) corrosion protection to steel in shipboard applications.

The U.S. Navy has two aluminum sprayed coating systems tailored to the operational environment the coated surfaces will see in service. Type I system provides for high temperature applications [surface operating temperatures greater than 79 degrees C. (175 degrees F.)] such as steam valves, and requires an aluminum coating thickness of 10-15 roils (0.010 to 0.015 inches) sealed with a heat resistant paint (Fig. 4.2).

The Type II system is for low temperature systems [surface operating temperature less than 79 degrees C. (175 degrees F.)] and is used for selected marine topside and interior applications. The Type II system consists of 7-10 roils (0.007 to 0.010 inches) of aluminum coating sealed with thinned epoxy polyamide paint (MIL-P-24441 /1) and topcoated with two additional layers of epoxy polyamide paint (Fig. 4.3).

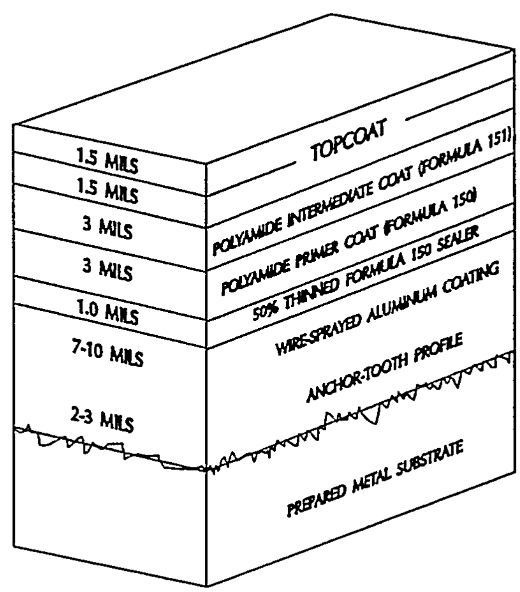


Fig. 4.3 Type II System for Low Temperature Applications

It is important to point out that the sealer/epoxy polyamide paint is chosen to make the aluminum system compatible with U.S. Navy painting practices. Type II systems for Navy ship application as shown in Fig. 4.3 require one additional camouflage/color topcoat. This topcoat can be one coat of MIL-P-24441 epoxy or alkyd haze grey enamel (TT-E-490). TT-E-490 is applied in two thin coats -1.5 mils per coat. Other topcoats may be required by individual ship specifications, or local air quality regulations.

4.4 Approved Applications per DoD-STD-2138

The following is a list of approved applications of metal spray coatings for corrosion control on Navy surface ships

Category I.
Machinery space components
(Type I, High Temp)

(a) Aluminum coating -10 to 15 mils thick
- (1) Low pressure air piping
- (2) Steam valves, piping and traps (except steam turbine control valves)
- (3) Auxillary exhaust (such as stacks, mufflers, and manifold)
- (4) Air ejection valves
- (5) Turnstile

Category II.
Topside weather equipment
(Type II, Low Temp)

(a) Aluminum coating -7 to 10 roils thick
- (1) Aircraft and cargo tie downs
- (2) Aluminum helo decks
- (3) Stanchions
- (4) Scupper brackets
- (5) Deck machinery and foundations
- (6) Chocks, bits, and cleats
- (7) Pipe hangers
- (8) Capstans/gypsy heads (except wear area)
- (9) Rigging fittings (block and hooks)
- (10) Fire station hardware
- (11) Lighting fixtures and brackets

Category III.
Interior wet spaces
(Type II, Low Temp)

(a) Aluminum coating -7 to 10 roils thick:
- (1) Decks in wash rooms and water closets
- (2) Pump room deck and equipment support foundations
- (3) Fan room decks and equipment support foundations
- (4) Water heater room decks and equipment support foundations
- (5) Air conditioning room decks and equipment support foundations
- (6) Deck plate supports
- (7) Machinery foundations
- (8) Boiler air casings (skirts)

4.5 List of Typical Shipboard TSA Coated Items

It is important to the success of the existing Navy corrosion control program and long term utilization that each shipyard use its experience and expertise to continually examine and suggest additional uses and applications for the thermal spray aluminum coatings systems. The following list represents some standard items that have been preserved using thermal sprayed aluminum coatings.

Arm, FAS Swivel
Assembly, FAS Swivel
Armbar, Chair
Base, P-250 Box
Blower, Soot
Bolt, Baxter
Box, P-250
Brace, Accom-Ladder
Bracket / Pipe, Light
Bracket, Bottle-Rack
Bracket, CO_2 Bottle
Bracket, Helo-Net Securing
Bracket, Scupper
Bracket, Searchlight
Controller, Capstan
Counterweight, Director
Coupling Pipe
Cover, lMC Speaker
Cover, Cable BPSMS
Cover, Chain Locker
Cover, Chock
Cover, Edge Light
Cover, Fuel Oil Vent
Cover, Handwheel
Cover, Hawse Pipe
Cover, Junction Box
Cradle, Life Raft
Davit, Portable
Director, Counterweight CWL
Dog, Wt Door
Door, Watertight
Ducting
Eye, Bolt Lifting
Fitting, NATO
Foundations, Machinery
Flange, Blank
Frame Net
Frame, Stanchion
Guard, Winch Safety
Handle, Strainer
Handrail, Debark
Handwheel, Various
Hatch (Large)
Hinge
Housing, Reel Shaft
Ladder, Vertical
Locker, Pyro
Manifold
Mount, FAS Bulkhead
Mount, Reel Line
Mount, Saluting Gun
Pad, Fairlead
Piping, FAS
Plate / Bracket, Light
Plate, Fuel Gage
Rack, Bottle Gas
Reel, Line
Relief Exhaust
Rod, Reach
Roller, Ramp
Roller, Stopper
Screen, Bullnose
Scuttle
Shackle, Unrep
Sheave, Fairlead
Shield, 50 Cal
Sign, Parking
Socket, Portable Davit
Stanchion
Valves, Globe
Valves, Governor
Valves, Reducer
Valves, Regulating
Vent, Fuel Oil
Wrench Anchor
Yoke, 50 Cal
Yoke Searchlight

4.6 Prohibited Applications Per DoD-STD 2138

Metal sprayed coatings for use in U.S. Navy corrosion control applications are intended for selected application to steel and aluminum surfaces. TSA coatings for corrosion control should not be used for the following

- Plastic, rubber, painted surfaces
- Internal surfaces of moving machinery (example pump casings, valves, etc.)
- Brass, bronze, copper-nickel or monel surfaces
- Stainless steels, 17-4PH, 15-4PH
- Surfaces subject to strong acids or bases (example aircraft catapult slides)
- Threads of fasteners, and valve stems
- Within ¾" of surfaces to be welded
- Steel alloys with yield strength greater than 120,000 lb/in^2
- Nonskid deck coatings (except as approved by NAVSEA for research and development evaluation)
- Exterior underwater hull surfaces
- Sanitary tanks interior

5. THERMAL SPRAYED COATING APPLICATION

5. THERMAL SPRAYED COATING APPLICATION

5.1 The Thermal Sprayed Aluminum Process

The Thermal Sprayed Aluminum (TSA) coating system consists of a properly prepared substrate to which a thermal sprayed aluminum coating is applied and subsequently sealed with organic paint, and top coated with paint as required to meet barrier, functional, or cosmetic requirements.

DoD-STD 2138 describes two TSA coatimz systems; one for components that experience high temperature operation conditions and the second for ambient conditions. Refer to Section 4.3 for system descriptions.

TSA coatings may be applied by using the combustion flame or electric-arc thermal spray process as discussed later in this section. The production process for applying the TSA coating system can be divided into five major production steps. Table 5-A summarizes the production work station functions and quality control (QC) checkpoints. Process control is further discussed in Section 7.

WORKSTATION	FUNCTIONS: PRODUCTION	FUNCTIONS: QC CHECK
1. Surface Preparation	• Solvent clean • Trisodium phosphate wash • Abrasive cleaning • Heat cleaning • Caustic bath	l Clean substrate
2. Masking	• Mask surfaces not to be coated	Ž Properly masked
3. Anchor-tooth Blasting	• 2-3 mil anchor-tooth • White-metal finish	• Al_2O_3 grit quality/size • Clean, dry air • SSPC-5 finish
4. Thermal Spraying	• Preheat substrate • Spray 90-45° to substrate and 5-8 in. standoff - 3-4 mil per crossing pass - 7-10 mil for <175°F service; 10-15 mil for >175°F service	• Substrate >10°F above dew point • Proper time between anchor-tooth blasting and start/-completion of spraying • Coupon bend test (equipment system check) • Thickness measurement • Visual examination
5. Sealing/ Painting	• ≤175°F service: 5-coat paint schedule; 10 mil total thickness • >175°F service: 2-coat paint schedule; 3 mil total thickness	• Wet film thickness • Minimum/maximum drying times between paint coats • Dry film thickness

Table 5-A Work Station Function and Quality Control Checkpoints

Items to be TSA coated are transferred by production personnel to various work stations for surface preparation, decreasing and masking, strip anchor-tooth blasting, thermal spraying and painting. Items to be TSA coated are anchor-tooth blasted to white metal with a 2-3 mil anchor-tooth pattern. Following anchor-tooth blasting, items are transferred immediately, generally within a few minutes, to the TSA coating station. The component is then aluminum thermal sprayed, sealed and painted in accordance with DoD-STD 2138 and ship specifications.

The Process Flow Chart in Fig. 5.1 represents a typical production flow to accomplish the TSA coating system. Numbers in parentheses refer to related sections of DoD-STD 2138.

Each facility that intends to apply TSA coatings should develop an internal industrial process instruction that details all the production and quality control checkpoints, such as equipment, consumable materials, safety, quality control, operator training and certification. The Navy's military standard for applying the TSA coatings is the primary technical reference for this process instruction. (See Appendix H).

NASSCO developed such a document during the early stages of their thermal spray program. This "Flame Spray Manual" was prepared by the Quality Assurance Department (Ref. 3). Following is an outline of the contents:

- Certification Requirements
- Equipment/Material Requirements
- Safety
- Surface Preparation
- Process Instructions
- Inspection/Testing Requirements

5.2 Types of Equipment for TSA Coating Applications

The thermal spraying processes and related equipment for the application of aluminum for corrosion control can be divided into two basic categories combustion and electric arc.

Combustion Spraying

Thermal spraying utilizing the heat from a chemical reaction is known as combustion gas or flame spraying (oxygen and a fuel gas). Any substance that does not sublime and that melts at temperatures less than 5000 F. (2760 C) may be flame sprayed. The materials used are metals (and alloys) in the form of wire or powder.

The equipment for thermal spraying with wire is similar to that shown in Fig. 5.2, and a typical wire thermal spraying gun cross section is shown in Fig. 5.3.

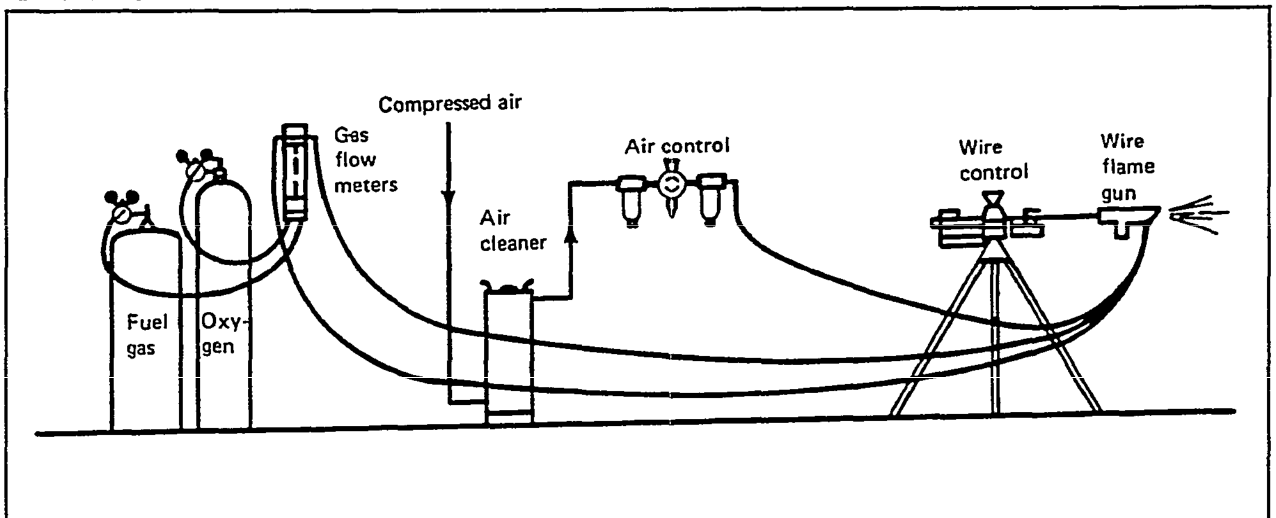


Fig. 5.2 Typical Combustion Wire Installation

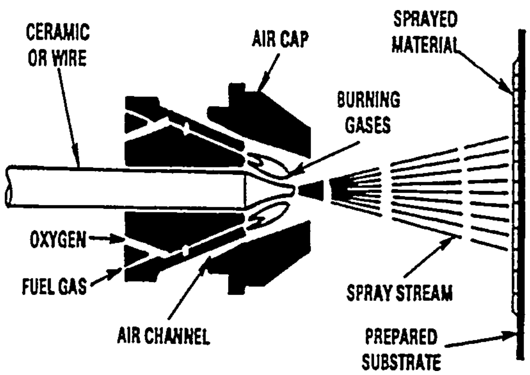


Fig. 5.3 Cross Section of Typical Combustion Wire Gun

The feedstock material (wire) is drawn by drive rolls into the rear of the gun. The rolls are powered by an electric motor, an air motor, or an air turbine. The feedstock proceeds through a nozzle where it is melted by the coaxial flame of burning gas.

One of the following fuel gases may be combined with oxygen for use in flame spraying acetylene, methylacetylenepropa-diene stabilized (MPS), propane or natural gas. Acetylene is widely used because higher flame temperatures are attainable. However, in many cases, lower temperature flames can be used with economic advantages. A fuel gas flame is used for melting only, and not for propelling or conveying the coating material. To accomplish spraying, the flame is surrounded with a stream of compressed gas, usually air, used to atomize the molten material and to propel it onto the substrate. In special applications, an inert gas maybe used in lieu of air.

Powder flame spray guns are lighter and more compact than other types of thermal spraying equipment. The powder feedstock may be a pure metal, an alloy, a composite, or any combination of these. The feedstock is stored in a hopper that may be integrated with, or connected to the gun. A small amount of gas is diverted to carry the powder into the oxygen-fuel gas stream, where the powder is melted and carried by the flame onto the substrate. The general arrangement of an installation for powder flame spraying is shown in Fig. 5.4, and a typical gun cross section is shown in Fig. 5.5. Variations in the powder flame spraying process include compressed gas to

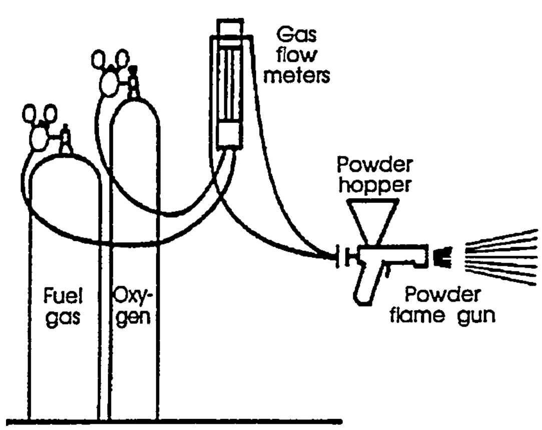


Fig. 5.4 ***Typical Combustion Powder Installation***

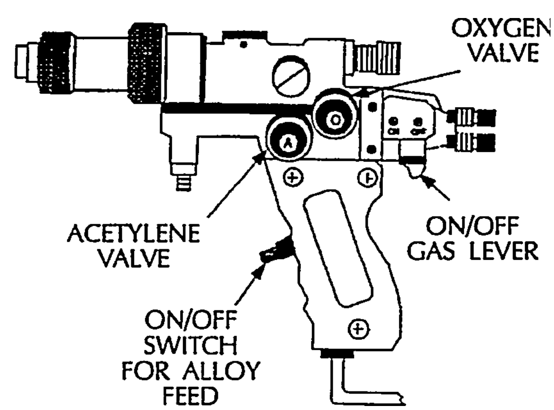


Fig. 5.5 Typical Combustion Powder Gun

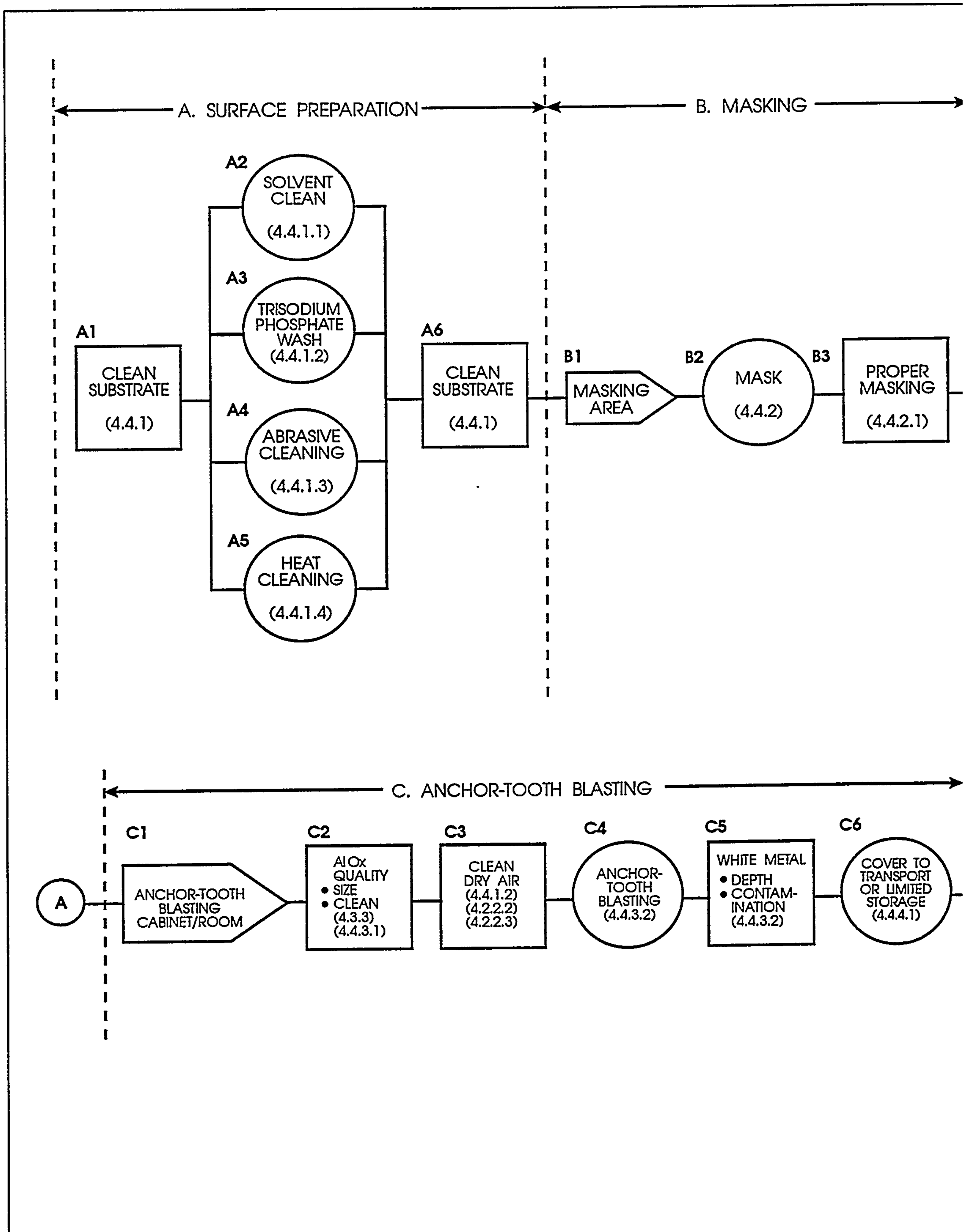


Fig. 5.1 Process Flow Chart

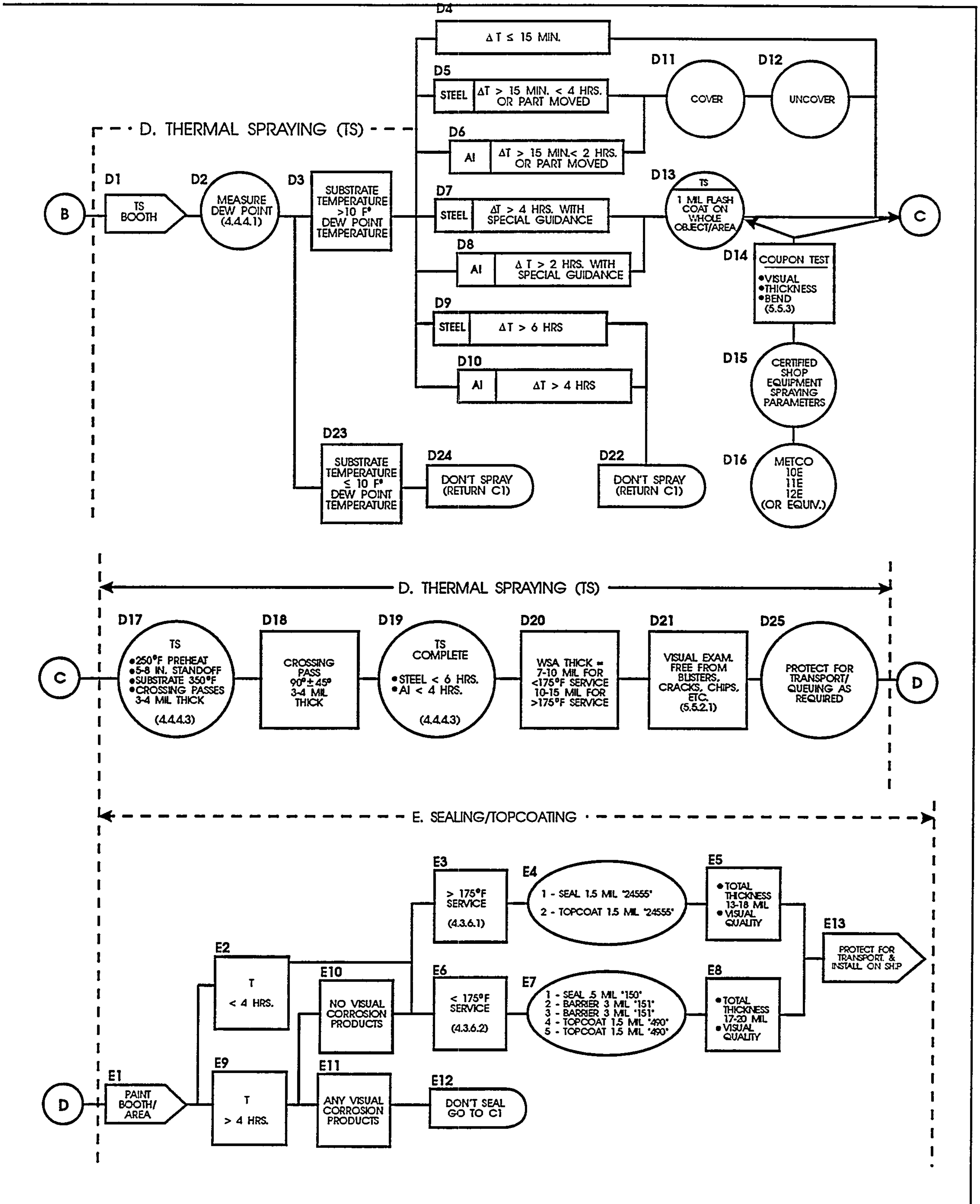


Fig. 5.1 Process Flow Chart (Cont'd.)

feed powder into the flame, additional air jets to accelerate the molten particles, a remote powder feeder with an inert gas to convey powder through a pressurized tube into the gun, and devices for high speed acceleration at atmospheric pressure. Such refinements tend to improve powder flow rate, and sometimes to increase particle velocity, which enhances bond strength and spray deposit density.

In all thermal spraying processes, the particle velocity affects the structure and the deposit efficiency of the coating. If the particle velocity is too low, some particles may be volatized and result in coating deterioration and elevated operating costs. If the wire or powder are not properly heated, deposit efficiency will decrease rapidly, and the coating will contain trapped, unmelted particles. Table 5-B compares the equipment working temperatures and particle velocities for each System.

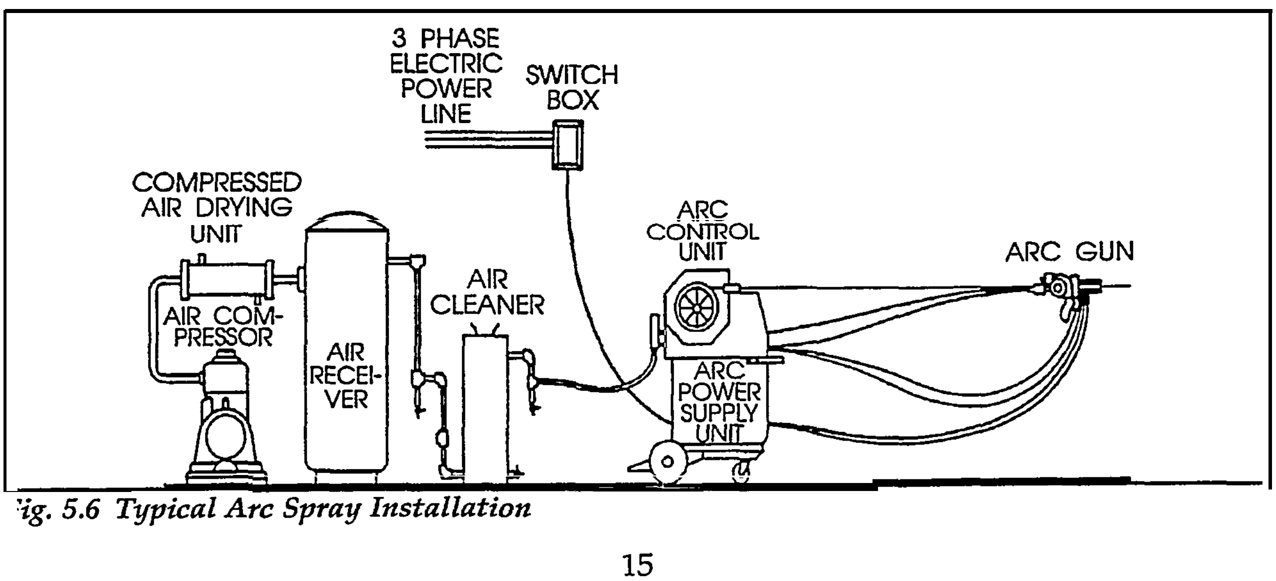
THERMAL SPRAY EQUIPMENT TYPE	PARTICLE VELOCITY, FPS	FLAME WORKING TEMPERATURE, F
Gas Combustion Heating		
Powder flame Spray	**80-120**	**4600-4800**
Wire Flame Spray	**800**	**5000-5200**
Electric Arc Heating		
Electric Arc spray	**800**	**1o,ooo-12,000**

Table 5-B Particle Velocity Comparison

Electric Arc Spraying

In the wire arc process, two consumable wire electrodes, that are at first insulated from each other, automatically advance to meet at a point in an atomizing gas stream. A potential difference of 18 to 40 voIts applied across the wires, starts an arc that melts the tips of the wire electrodes. An atomizing gas, usually compressed air, is directed across the arc zone, shearing o: molten droplets which form the atomized spray. The arc spray system is comprised of components as illustrated in Fig. 5.6.

The arc spray gun is illustrated in Fig. 5.7. Wire electrodes are fed through wire guides and into the contact tips. The atomizing nozzle conducts the compressed air and directs it across the arc zone. Insulated power cables connect the gun to the DC power source. Arc guns also include mechanisms for feeding the wire at a controlled rate. Contact tips are sized for a particular wire diameter. ON and *OFF* switches are provided on the gun to control the wire feed, compressed air supply, and electric power supply. The arc temperatures considerably exceed the melting point of the spray material. During the melting cycle, the fed wire is super heated to the point where some volatilization may occur. The high particle temperatures produce metallurgical interactions or diffusion zones, or both, after impact with the substrate.



'ig. 5.6 Typical Arc Spray Installation

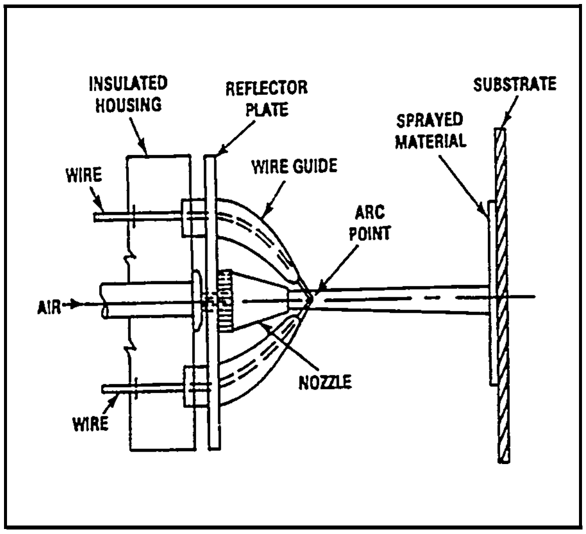


Fig. 5.7 Cross Section Schematic of an Arc Spray Gun

These localized reactions form minute weld spots with good cohesive and adhesive strengths.

The arc process normally has higher spray rates than other spray processes. Factors controlling the application rate are the current rating of the power source and the permissible wire feed rate to use the available power. Section 9 discusses the economics of the arc and combustion processes.

Typical arc wire systems require DC power source providing a voltage between 18 to 40 volts. Constant potential power sources are usually used. The arc gap and spray particle size increase with a rise in voltage. The voltage should be kept at the lowest level, consistent with arc stability, to provide smooth, dense coatings and improved deposit efficiency.

The arc wire control unit is comprised of two reel or coil holders, which are insulated from each other. Wires of larger diameters are usually in coil form, while smaller diameter wires are preferably layer level wound on reels or in barrels. The unit is connected to the gun by flexible insulated cables.

The control console incorporates the switches and regulators necessary for controlling and monitoring the operating circuits that power the gun.

5.3 Surface Preparation Procedures

Surface preparation is the foundation of a correctly applied thermal sprayed coating. Coating adhesion is directly related to the cleanliness and the roughness of the prepared surface. Adherence to qualified procedures in preparing a surface is necessary to ensure successful application of the thermal spray coating.

Pre-Cleaning

The first step in the preparation of a substrate for thermal spraying is to remove all surface contaminants such as scale, oil, grease and paint. The heat of spraying will not remove contaminants, and contamination will inhibit bonding. After all contaminants have been removed, the cleanliness should be maintained until the spray cycle has been completed.

Hot vapor degreasing is a common, economical, and efficient method for removing organic contaminants. Parts should be soaked fifteen to thirty minutes to remove oil from surface pores. Porous materials, such as sand castings or cast irons, should be soaked for longer periods. If objects are too large for vapor decreasing, steam cleaning, submerging in hot detergent solutions, or manually cleaning with a solvent that is oil free may be required. Chlorinated solvents leave a slight residue that can be removed by immersion washing or wiping with isopropyl alcohol. Residue should be mechanically removed.

The use of common degreaser solvents such as perchlorethylene, trichlorethylene and 1,1,1 trichlorethane, is not currently recommended due to more stringent Federal and local air quality regulations. Most

hydrocarbon solvents are hazardous, and manufacturer's instructions should be followed regarding usage, location and disposition. Investigate the local EPA or Hazardous Waste Regulations for use and disposal of solvents before selecting the materials. Also, the potential recycling of solvents should be investigated with the supplier. Non-hazardous, biodegradable cleaners or detergents should be used whenever possible.

Various components manufactured from porous materials such as castings, may absorb considerable quantities of oil. This oil may bleed out during a subsequent spraying operation, even after precleaning using vapor decreasing or solvent or detergent washing. Welded assemblies that have received fluorescent penetrant inspection are particularly subject to this condition. Oven baking at 600 degrees Fahrenheit for four hours dries the oil and prevents bleed out.

Ultrasonic cleaning can be used when contaminants are lodged in confined areas. The equipment consists of a holding tank for the cleaning solution and a source producing ultrasonic vibrations within it.

Strip Blast Cleaning

Dry abrasive blasting, commonly described as strip blasting, is an effective method for removing baked-on deposits, scale, paint or oxides. Abrasive blasting is accomplished by directing a compressed air steam containing abrasive particles through a nozzle to the surface. The blasting operation should be conducted by equipment other than the unit assigned for the final (anchor-tooth) blasting of substrates for spraying. This prevents contamination of the blasting materials.
The object of this cleaning technique is to ensure there are no contaminants remaining on the surface that will prevent maximum adherence of the thermal sprayed aluminum coating.

Masking Techniques and Materials

For some components, only specific areas of a workpiece may need to be coated. (Section 4.6 defines prohibited areas of TSA application) In such cases, there are areas that must be protected, both from unnecessary surface roughening and from adherence of the sprayed material. The technique of protecting the areas not to be blasted or sprayed is called masking. Different masking materials and techniques may be required for grit blasting and for spraying, though commonly the same mask may be used for both operations. Some masking materials used with success are listed in Table 5-C.

For most grit-blast masking applications, ordinary rubber tape or duct tape, applied several layers thick, affords satisfactory protection to surfaces. These materials have the advantage of being inexpensive and easy to cut or shape as needed. Adhesive-backed silicon tapes provide the required protection for abrasive blasting and thermal spraying, and are less likely to be damaged by abrasive blasting and spraying than duct or rubber tapes. However, silicone tapes are approximately five times more expensive than duct tape.

Metal or rubber shields may be used, provided the geometry of the workpiece is not too complex. Of the two materials, rubber is the better choice as a grit blasting mask because it is not cut by the grit blast abrasive, whereas a metal mask will ultimately erode. However a metal grit blasting mask may be used as a thermal spray mask as well, while rubber, except silicon, cannot. Provisions must be made, when using metal masks, to prevent coating build-up on them. This may require that the masks are coated with a suitable "stop-off' material, or equipped with some mechanical means of removing deposited material. The use of metal or rubber shields is generally limited to flat or cylindrical surfaces.

DESCRIPTION	PRODUCT IDENTIFICATION	FORM	METHOD OF APPLICATION	FOR GRIT BLASTING	FOR COATING	METHOD OF REMOVAL
Silicon resin backed tape	Bron 18647	Tape	Manual	X	X	Peel
Fiber glass tape	Bron BT1077 Insulectro 06004	Tape	Manual		x	Peel
Vinyl tape	3M Scotch #33	Tape	Manual	x		Peel
Liquid masking	Metco Antibond	Liquid	Brush		x	Water wash or brush
Commercial grade Silicon	Silicone	Tubing, sheeting, plugs	Cut as templates and place manually	x	x	–
Liquid masking	Tafa Spray Guard	Liquid	Brush Dip	x	x	Peel
Duct tape	—	Tape	Manual	x	x	Peel
Metallic masks	—	Steel- 12-16 ga.	cut to fit	x	x	

Table 5-C Description Of Masking Materials

Another masking technique suitable for thermal spray applications is the use of liquid masking compound. These compounds, when applied to areas adjacent to the desired deposit area, act as stop-offs to prevent the adherence of the sprayed materials to the base metal. They may be applied by painting or dipping prior to or following grit blasting, making them easy to use. Threaded holes, slots, and key ways can be protected from thermal spraying by metal, silicon rubber, or carbon inserts.

Anchor-Tooth Blasting

After cleaning and masking, abrasive blasting is used to produce a surface that will maximize the adherence of the sprayed aluminum coating. Proper roughening is as important as cleaning. During thermal spraying, the plasticized molten particles form as platelets upon impact with the substrate. The platelets, as they cool and harden, must adhere to the prepared surface that will provide the mechanical adherence (bond strength).

Surface roughening by abrasive blasting is used to strengthen both the coating and the bond by

- providing compressive surface stresses
- interlocking laminations (or layers)
- increasing the bond area
- decontaminating the surface

The degree of roughness and general surface condition required to produce a receptive surface for the thermal sprayed aluminum coating is defined in DoD-STD2138 as follows

• The blasted surface will have a white metal blast appearance with an anchor-tooth (not peened) surface profile of two to three roils and validated with profile tape and a dial micrometer.

• Blasting will be done according to the requirements of SSPC No. 5 (or NACE No. 1). A white metal blast cleaned surface finish is defined as a surface with a gray-white, uniform metallic color, roughened to form a suitable anchor pattern for thermal sprayed coatings.

• The surface when visually inspected will be free of oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or any other foreign matter.

• Prepared surfaces will be handled only with clean gloves, rags or slings. Contact with any oil or grease will result in failure of the coating.

• Blasting will not be so severe as to distort the component being prepared for the thermal spray process.

Abrasive Grit

The effects of grit blasting depend on the type and size of abrasive. Sharp, hard, angular particles provide the best results. Spherical or rounded particles should not be used. All abrasives must be clean, dry, and free of oil, or other contaminants.

The most common types of grit used in thermal spray are aluminum oxide and chilled iron grit. These are the only two materials that are approved under DoD-STD 2138 for the final anchor-tooth blasting prior to the thermal sprayed aluminum coating. Garnet and copper slag are generally used for precleaning prior to the final anchor-tooth preparation. They are used primarily due to their low cost. Since the roughness of the finish depends on the size of the grit, abrasives are furnished in different grades. Smaller sized particles will allow for the preparation of more area per hour. Larger abrasive particles produce rougher finishes. It is recommended that the particle size should be 16 to 40 grit for the final preparation for thermal sprayed aluminum coatings and 16 to 60 grit for strip or precleaning blasting.

Adhesion bond strength normally increases with surface roughness, although the value does not improve above the maximum bond strength once the surface profile of three roils is achieved. The adhesion strength conversely drops off dramatically if the anchor-tooth pattern is below two roils. In accordance with DoD-STD 2138, the acceptance criteria for an anchor-tooth profile is two to three roils. There is some controversy in the industry concerning profiles greater than three roils. Profiles over three roils do not increase the bond strength and theoretically require more processing time and cost to (a) achieve a deeper anchor-tooth than required, and (b) apply the TSA coating to fill the profile completely.

There is, however, no loss of effectiveness of the TSA coating system due to excessive anchor-tooth profiles. In no case should an anchor-tooth profile in excess of three mils be considered detrimental to the TSA coating system. Proper training of operators to achieve the required 2-3 mil profile seems the most practical solution.

Blasting Procedures

Besides the abrasive grit type and size, other process variables of importance are air pressure, blast angle and distance. Air pressures for blasting are between 30 to 100 psi depending on the substrate material, flow, size of abrasive particles and the machine and nozzle type used. Low blasting air pressures should be used for very thin substrates to minimize the like-Iihood of warping damage to the component. With pressure type blasting equipment, 50-60 psi at the nozzle should be

used. These are not the pressures at the blast machine tank, but at the blast nozzle as measured with a needle probe gauge. When syphon blasting (suction blasting), the maximum nozzle pressure should be between 75-80 psi.

The compressed air supply should be adequate to furnish the necessary pressure and volume to sustain the proper blast quality. Refer to Table 5-D. The air should be free from oil, water, and other contaminates. Besides clogging the system, oil or water in the compressed air can adversely affect surface preparation and subsequent bonding. The requirements for air quality are defined in DoD-STD 2138. The air equipment used in the abrasive blasting process shall furnish air that is free of oil and moisture (less than 0.03 parts per million (p/m) oil). The abrasive stream should be directed onto the substrate surface at the same spray angle as the application of the TSA coating, which is normally between 45-90 degrees. Nozzle to substrate distance varies from 4- 12 inches depending upon the size and type of abrasive used, nozzle opening size, and capacity of the blast machine.

Blasting Rates

Blasting rates depend on several factors including the type, size, and loading capacity of the blasting equipment as well as the substrate material. Blast machine nozzles having large diameter orifices will cover more area per hour than nozzles having smaller orifices. However, the size

NOZZLE DIAMETER, IN.		NOZZLE PRESSURE, PSI					
		50	60	70	80	90	100
1/8	cfm air	11.3	13.2	15.1	17.0	18.5	20.3
	lb/hr	67.0	77.0	88.0	101.0	112.0	123.0
	hp required	1.6	2.1	2.5	3.1	3.5	4.2
1/4	cfm air	47.0	54,0	61.0	68.0	74.0	81.0
	Ib/hr	268.0	312.0	354.0	408.0	448.0	494.0
	hp required	6.4	8,3	10.2	12.4	14.2	16.8
3/8	cfm air	103.0	126.0	143.0	161.0	173.0	196.0
	Ib/hr	668.0	764,0	864.0	960.0	1052.0	1152.0
	hp required	14.8	19.3	23,9	29.3	33.2	40.6
1/2	cfm air	198.0	224,0	252.0	280.0	309.0	338.0
	Ib/hr	1160.0	1336.0	1512.0	1680.0	1856.0	2024.0
	hp required	26.7	34.3	42.1	51.0	59,3	70.0

Table 5=D Air, Grit Flows and Power Requirements for Blast Nozzle Sizes

of the nozzles to be chosen is limited by the amount of compressed air available. The type and size of the abrasives also influence blasting rates. Generally, the larger the abrasive particle size, the slower the operation. Approximately fifteen pounds of aluminum oxide or twenty-five pounds of chilled iron grit are required per square foot of blasted surface to achieve a properly prepared surface. Approximate blasting rates for various equipment types are shown in Table 5-E.

Grit Recycling

Some abrasives used in shop or production applications may be recycled, cleaned, and screened so that they can be used again. Angular chilled iron grit and aluminum oxide are most commonly used in such operations. When an abrasive is reused, it should be cleaned of dust and resized, with a minimum of 80% conforming to the original size requirements. Contaminated abrasive grains, or those of questionable quality, should not be reused. Failure to remove broken down grit (fines) from the abrasive can be detrimental to the proper bonding of a coating.

GUIDE TO BASE METAL GRITBLASTING RATES FOR NACE* NO. 1, WHITE METAL FINISH

EQUIPMENT	RATE, FT^2/HR MINIMUM	MAXIMUM
Pressure type	20	40
Manual abrasive return room	30	60
Automatic abrasive return room	50	160
Wheel type airless (per wheel)	150	400

Notes:

The minimum rate indicates the output on small work heavily corroded requiring considerable handling.

The maximum rate is for large surfaces in semi-bright or lightly corroded conditions.

*National Association of Corrosion Engineers

Table 5-E Gritblasting Rates

Table 5-F shows frequently used materials evaluated under controlled conditions. There are many variables that can alter this data, but the table gives a relative idea of the number of times different types of material can be recycled through a blast machine.

ABRASIVE LIFE

MATERIAL	NO. OF RECYCLES
Aluminum oxide	10
Chilled iron	15
Steel	100
Garnet	

Table 5-F Abrasive Recycling

Provisions should be made to incorporate enclosures to capture the spent abrasives used in on-block or on-ship applications. In addition, reclaiming/cleaning devices should be used wherever possible to maximize grit usage.

5.4 TSA Coating Procedures

The thermal sprayed aluminum process is operator technique dependent. only personnel who have been certified to Dod-STD 2138 and have received the proper training should operate the spray gun, and all process instructions must be strictly adhered to. Prior to application of thermal sprayed aluminum, all areas to be coated must be pre-planned in regard to spraying technique. Consideration must be given to the potential for overspray at an improper gun angle or distance, in addition to following all of the required parameters.

Manufacturers of thermal spray equipment have defined procedures to properly set-up the equipment. General procedures are as follows:

• Review parameter records.

• Ensure gun has appropriate hardware.

• Check, clean and connect all hoses and cables to gun.

• Test run system to ensure operation is correct.

Operator Technique

Prior to the production application of TSA coating, the operator is required to demonstrate that the equipment and process techniques are correct by preparing and spraying a test sample (3 inches by 2 inches by 0.050 inch) with 7-15 mils of aluminum. These samples are called Bend Test Coupons and they serve as a pre-production verification that all procedures are being correctly followed. The anchor-tooth profile and coating thickness are recorded daily on a shop traveler or log, showing the items that will be processed by that particular operator. Each sample is bent in accordance with the requirements of DoD-STD 2138. Results are evaluated and recorded. (Refer to Section 6 for acceptance criteria and procedures for the Bend Test.)

In the event the Bend Test fails to meet the acceptance criteria, no processing can commence until the procedure or equipment has been rechecked to determine the cause. Once the deficiency has been corrected a second test panel can be processed and tested. If an operator cannot successfully produce an acceptable Bend Test sample the second time, that operator is required to be retrained and his certification will be revoked until he has been retrained and retested. (Refer to DoD-STD 2138, Para. 5.4.2.1) The operator cannot spray any production components until he has been recertified. Prior to starting TSA coating the operator should mentally pre-plan the spraying techniques he will employ to produce the highest quality application possible.

The operator should look for the following

• An identifying area to start the coating, and be able to come back to that area for the second or third pass to ensure coating coverage.

• Areas which require angle heads or extensions.

l Areas where potential overspray at the wrong distance or spray angle will cause poor adhesion or excessive porosity.

• Areas where the masking may deteriorate due to the heat generated by the coating.

• Sharp edges or corners where the coating may be chipped or damaged if the maximum coating thickness is applied. Ideally, all edges and comers should be rounded or radiused prior to coating. Edges are the weak link in any coating process.

Each operator should develop the skills to determine audibly or visually if a thermal spray gun is operating correctly. This audible skill may take years to perfect but experienced operators can tell if a gun is operating correctly by the pitch the gun emits during processing. The visual skills are more definable; the following list describes the visual characteristics operators should be capable of determining:

• The spray texture of the deposited coating

• Flame or arc color

• Flame definition (sharpness)

Ž Length and condition of the melting tips of the wire

• Water or oils present on the gun or hoses

Operators also should develop the skills to recognize variation from the correct operating parameters and have the ability to correct them. During the coating application, operators should monitor the operating parameters, i.e., pressure/flows or voltage/amperage to detect any variations in the pre-established values. The TSA coating process success is directly proportionate to the skill, knowledge level and dedication of each operator. Most thermal sprayed coating failures occur due to poor operator technique. All application parameters have a tolerance range within which the TSA coating will be acceptable. If the operator keeps the application techniques in this range, he can be assured of the success of the coating.

Coating Characteristics

An inherent characteristic of the coating process is the stress created by the cooling of each particle during spraying. Stress is the combination of thousands of particles shrinking due to the quenching effect of the molten particles impinging on the cool work piece. The coefficient of expansion and contraction of aluminum is substantially greater than other materials. The stress factor can be controlled but if it is not, stresses can exceed the bond strength of sprayed aluminum and the coating can disbond.

The combination of the bond and cohesion strength make up the overall bond of the coating to surfaces. The difference between bond strength and cohesive strength is as follows:

Bond Strength That first layer of particles that are in intimate contact with the prepared base materials. The bond strength should always be greater than the cohesive strength of the coating.

Cohesion Strength The adhesion strength of particles to particles generally defined as cementation.

To keep the stresses at a minimum, the aluminum coating should be applied in multiple passes that will reduce the number of particles impacting any one area. The gun movement relative to the target is the controlling factor. Each operator, through hands-on training, will be abIe to optimize their technique for applying the coating in multiple passes. The spray pattern or overlap between passes is another technique the operators must perfect. For combustion spraying with a standard air cap, the coating will be applied evenly with overlaps of 5/8" - 3/4." There are fan air caps available for the combustion wire systems to extend the spray pattern to 2" - 3" wide. The fan air caps should only be used for large flat surfaces.

For arc spraying with standard air caps, the coating will be applied evenly with overlaps of approximately 1" - 1½." With fan air caps, the spray pattern can be increased up to 6" and overlaps up to 5" will produce even coatings. The fan air caps should again, only be used for large flat surfaces.

Angle air caps, nozzles and extensions are readily available for the combustion powder and wire systems, with limited availability for the arc spray systems. These angle spray devices permit the coating of areas where a straight spray pattern will not cover adequately. They provide up to a 45 degree spray angle while the gun is pointed straight. The extensions can be very helpful to spray areas where an operator's arm cannot reach. These extensions are manufactured up to a standard length of three feet, although longer lengths can be special ordered. For both combustion wire or powder and electric arc systems, the use of angle heads and extensions reduce the pounds per hour capabilities by approximately 20%.

Correct overlap is an important technique to ensure an even deposit across any given surface. In any hand-spraying application, it is virtually impossible to maintain the

required overlap consistently. One technique used to help maintain an even coating deposit is to make the second or "crossing pass" at right angles to the original pass. This technique will maximize the efficiency of the coverage.

When applying TSA coatings over blasted steel surfaces, there is a slight color difference between the TSA and the blasted surface. (The TSA is white and the blasted surface is light gray). Operators can visually see where they have coated. However, making subsequent passes over previously TSA coated surfaces is more difficult since there is no visual way an operator can determine where the subsequent passes have started or stopped. The only way to determine the coverage is by measuring coating thickness. Therefore, it is strongly suggested that only small areas (approximately two square feet) are processed at a time. This will allow an operator to concentrate, and not lose track of where he started or where the next overlap pass will start.

The drawback to processing small areas is the potential for other prepared surfaces awaiting the TSA coating to become contaminated. Also, the time between blasting and coating may be a factor if the allowable time per DoD-STD 2138 has run out and the surfaces are required to be reblasted. In some cases, to eliminate the requirement of reblasting any surface, a flash coat of 1 - 2 roils applied over the prepared surface will prevent unnecessary duplication of processing steps.

Coating Application

A localized preheating procedure to eliminate any surface moisture on the substrate is recommended prior to application of TSA coatings. A preheat temperature of 125-150 degrees Fahrenheit is a good standard practice for thermal spraying. The surface temperature should not exceed 350 degrees Fahrenheit any time during the spraying process. If the steel substrate temperature of the item to be sprayed is less than 10 degrees Fahrenheit above the dew point, no thermal spraying should be conducted.

To ensure proper application, a spray distance of 5" - 8" at a 90 degree angle (perpendicular) is the optimum condition. A spray angle of 45 degrees is the minimum acceptable angle. Beyond a 45 degree angle, the particles will shadow the next particle and prevent it from flattening out. This causes excessive porosity within the coating structure and poor bond strength and cohesion strength.

After anchor-tooth blasting, the TSA coating should be applied to the desired surface as soon as possible. DoD-STD 2138 mandates that in no case should a component be sprayed after six hours has elapsed. The TSA coating operation should be started within four hours after final anchor-tooth blasting, and finished within Six hours. Parts not sprayed within six hours are to be lightly reblasted to remove surface oxidation and then sprayed. If any flash rust, discoloration or contamination occurs on a blasted surface, that part must be reblasted to white metal prior to continuing the spray process.

The optimum coating thickness per pass is 3-4 mils and the optimum total coating thickness is 7 - 10 roils for parts whose operating temperatures are below 175 degrees F. For parts whose operating temperatures are above 175 degrees, the optimum total coating thickness is 10-15 mils. The rate of gun movement and indexing (overlapping) will create the proper thickness per pass.

	HIGH TEMP. (TYPE I)	LOW TEMP. (TYPE II)
Optimum	10-15mils	7-10mils
Acceptable	10-20 roils	7-20 roils

Table 5-G Coating Thickness Range

The coating thickness should be measured with a magnetic or electronic thickness gage. Each operator should initiate their own quality control checks prior to any formal inspection. It is recommended that the operators perform preheat temperature and thickness readings during the processing, and that they thoroughly check for coating thickness prior to final inspection.

In any case, if the coating thickness is greater than 20 roils, the coating must be removed by abrasive blasting and then resprayed to the proper thickness. If the coating thickness is less than 7 mils and no surface contamination has taken place, additional coating can be applied to obtain the required thickness. If surface contamination occurs, a light blast should adequately prepare the surface and the part can be resprayed. If the contamination consists of oils or grease, solvent degrease and remove all residue and prepare the area by lightly blasting. The part can then be resprayed.

Sealing the TSA Coating

Thermal spray coatings are inherently porous. Porosity can range from less than 1% to greater than 15%. If the coating is improperly applied, particularly with complex shapes, this porosity may extend from the coating surface to the substrate. Sealers are used as a post treatment to fill such pores. Reasons for sealing sprayed coatings are:

- Prevention or retardation of corrosion at the coating/substrate interface.

- Life extension of aluminum corrosion preventive coatings.

Sealers must be applied to clean, dry, flame-sprayed surfaces. Any oil, grease, or other contamination on the aluminum coating must be removed by washing with a thinner compatible with the sealer.

Use TT-P-28 (environmentally compliant) heat resistant aluminum paint on sprayed surfaces of components operating at temperatures greater than 175 degrees. A 1.5 mil dry film thickness is required per coat for a total of 3 roils. For components whose operating temperature is less than 175 degrees F., use Formula 150 (MIL-P-24441-IC) epoxy at one mil or less for the sealer coating. Dilute the epoxy 50% by volume with an approved epoxy thinner before applying the seal coat. (NOTE: This thinned epoxy sealer will be specified in the revision to DoD STD 2138.) Subsequent full coat paint systems compatible with the diluted Formula 150 are applied over the sealer.

6. TRAINING AND CERTIFICATION

6. TRAINING AND CERTIFICATION

As discussed in the previous section on TSA coating procedures, the success and quality of the thermal spray process is almost completely operator dependent. This applies not only to the deposition process but also to the preparatory processes, and ultimately, the end product. Controls must be applied to all phases of the operation to assure a consistently dependable product. Each operator must be thoroughly trained, tested and certified before performing this process. (Refer to Sect. 7, Process Control)

The Navy has issued an Operator Certification requirement in DoD-STD-2138, and certain other industries also require certification acknowledging proficiency with the degree of compliance determined by the user. Before operators handle or use any thermal spray equipment, they should be trained in basic safety, equipment and tool handling, and have a good familiarity with manuals and instructions. The following is a list of the key elements included in a comprehensive training program:

- Presentation of safety precautions and process procedures that yield acceptable quality deposit
- Equipment and process description including discussion and demonstrations by qualified personnel
- Trainee self-study period on previously supplied manuals and processing instructions
- Supervised process operation on-the-job training with qualified personnel
- Maintenance and repair of equipment
- Solo process operation with frequent performance review by qualified personnel
- Performance evaluation

Generally, a thorough training period, encompassing all processes, may require as much as 4-5 weeks, with the final weeks devoted to solo on-the-job operation and testing. The training period should be divided into segments; for example

Safety
- Demonstration of safety devices
- Demonstration of operating equipment
- Self-study (reading)
- Testing (written/oral performance)

Surface Preparation
- Process description
- Demonstration of safety practices
- Solo
- Testing (performance)

Wire or Powder Flame, and Arc Spraying
- Process description
- Demonstration of safety practices
- Self-study (reading/hands-on)
- Equipment construction and assembly
- Trouble shooting
- Solo
- Testing (written/performance)

Upon completion of the required training, the proficiency of the candidate should be evaluated. Testing will be either written or oral, with a hands-on demonstration of skills. The written or oral test should contain questions directly related to the text or subject material. True-or-false or multiple choice is best. The actual tests should be direct and to the point. Individual tests should be provided for each subject, i.e., Safety, Surface Preparation, Wire and Powder Flame Spraying, Wire Arc Spraying. (A sample operator written certification test is shown in Appendix D.) The purpose of the spray test is to enable the candidate to demonstrate required skills as a craftsman. Hence, the coating visual appearance, thickness control, temperature during application, and amount of overspray all should be evaluated.

6.1 Operator Training and Qualification per DoD-STD 2138

Operator training shall consist of a minimum of a one week course to include three days of classroom study (e.g., corrosion control theory, metallizing technique, safety, gun maintenance and quality assurance), followed by two days of hands-on gun operation and maintenance. In addition, 40 hours minimum of spraying production parts with authorized supervision is required. Each operator shall demonstrate the ability to field strip, clean and lubricate the spray gun. The operator also should demonstrate the same ability to effectively trouble shoot the gun on the job. Immediately after gun reassembly the operator shall spray test coupons.

The test coupons for operator certification are as follows:

- Four bend test coupons sprayed on one side with a coating thickness of 7-10 roils.
- Five tensile (bond) test coupons sprayed on one end with a minimum coating thickness of 15 roils.
- Two shape test (one "T" and one Round) sprayed on all external surfaces 10-15 roils thick.

All test coupons will be evaluated according to the acceptance criteria for the appropriate tests (visual, bend and tensile).

Certification will be validated by the Quality Assurance Department and a NAVSEA (SupShip) representative. Some or all of the certification may be handled by supervisory personnel, provided concurrence with Quality Assurance has been obtained.

Operator certification will be retained as long as a period of six months does not lapse between production use of the applicable thermal spray process. Production use shall be defined as performing thermal spraying operations at least eight hours in a consecutive thirty day period.

Operators whose certification has lapsed may be recertified by satisfactorily completing the qualification text. Any operator failing the initial certification test may be permitted to perform one retest for each type of test failed. If the operator fails the retest, he will not be certified until completion of training or retraining and subsequent complete certification retesting.

6.2 Facility and Operator Certification Requirements

Any shipyard desiring to set up a TSA facility is required to have a facility survey and approval, along with certification of operators by a NAVSEA Representative. The following steps are necessary to obtain both a facility and operator certification approval.

- Acquire all necessary equipments to comply with requirements of DoD-STD 2138.
- Obtain training from an authorized source for all operators.
- Write and submit to NAVSEA a shipyard process control document defining equipments, procedures and controls to accomplish the TSA coating.

Note NAVSEA point of contact is the local Supervisor of Shipbuilding (SupShip).

- Submit a written request to NAVSEA to obtain a facility survey/audit.
- Submit a written request to NAVSEA to witness each operator's ability to perform the operator certification tests.

- Submit all test data, physical and written, to substantiate the operators' certification.

- Establish an internal procedure to inspect subcontractors facilities and certifications if said contractor will be accomplishing TSA work for the shipyard.

- Establish an internal procedure to perform inspections on all incoming subcontractors work.

A sample checklist for facility and equipment certification in accordance with DoD-STD 2138 is shown in Fig. 6.1.

Training Costs

Facilities requiring an independent company to furnish a complete training program must ensure that company has been authorized and approved by NAVSEA. The current cost range for a four week training program including all written and physical testing for a maximum of ten trainees is $6,000-7,000. This cost does not include transportation or per diem.

West Coast sources for obtaining NAVSEA approved training programs for operators and facilities are as follows

FLAME SPRAY, INC.
4674 Alvarado Canyon Road
San Diego, CA 92120
(619) 283-2007
FAX (619) 283-5467
Contact: Larry Suhl

Advanced Systems Technology, Inc. (AST)
7675 Dagget Street, Site 350
San Diego, CA 92111
(619) 974-7667
FAX (619) 279-7744
Contact: Owen O'Brien

Other authorized training agencies may be identified by contacting NAVSEA Code 0514, Washington, D.C.

FLAME SPRAY CERTIFICATION REQUIREMENTS*

Facilities Certification Checklist

Prior to employing the Wire Sprayed Aluminum (WSA) process for the purpose of corrosion control, all in-house a subcontractors' flame spray facilities, procedures and operators shall be certified in accordance with DoD-STD-2138.

This section identifies each certification requirement and serves as a checklist for NAVSEA and QA inspection results.

FACILITIES AND EQUIPMENT

Abrasive blasting booths are provided with the following:

- Steel blasting bench or cabinet ________
- Oil and moisture separators ________
- Pressure regulators and gauge ________
- Blast nozzle with a dead-man valve ________
- Proper abrasive media ________
- Metal coupons required for sampling ________
- TESTEX, Press-O-Film Tape or equivalent ________
- Micrometer (current calibration traceable to NBS) ________
- Equipment is capable of producing an uncontaminated 2 to 3 mil surface profile ________
- Sufficient equipment is available to provide adequate ventilation when blasting in enclosed shipboard areas ________
- All operators are required to wear air supplied respirators. ________

Flame Spraying Booths

- Wet spray booth surfaces are constructed to prevent dust from being expelled from the booth. ________
- Wet collectors and exhausters are capable of providing for an air flow of at least 200 cfm/ft^2 of booth opening. ________
- Enclosed area air exhausts are located near the floor. ________
- Ducting provides for an air velocity of at least 2000 feet per minute. ________
- Air respirator masks, and eye and ear protection devices are provided for each operator. ________

Certification of equipment is based on the flame-spray gun identified in the applicable WSA application procedure.

- Available equipment is adequate to perform flame-spray operations. ________

Special clothing required for blast operators working in enclosed spaces.

- Helmet with airline respirators ________
- Protective jacket and trousers ________
- Safety shoes ________
- Leather or rubber gloves ________

Fig. 6.1 Facilities Certification Checklist

*Taken from NASSCO's Flame Spray Manual (Ref.

7. PROCESS CONTROL

7. PROCESS CONTROL

7.1 Quality Assurance

Quality assurance is the responsibility of all personnel directly or indirectly involved with the thermai sprayed aluminum (TSA) coating process. Each shipyard has their own quality system, and the corporate management objectives regarding quality should be clearly defined. Implementation and control is the responsibility of all members of the particular organization. The effectiveness of the TSA coating process will only be successful if the commitment to quality is maintained.

The operator technique dependency of the TSA coating process demands that each operator is responsible to meet or exceed the acceptance criteria for the coatings. Each step in the processing is a key ingredient to producing a quality product. Any steps not correctly performed within the requirements of DoD-STD 2138 may lead to premature coating failure, thus jeopardizing both an organization's credibility and the validity of the TSA coating process throughout the industry. The only way an organization can continually produce acceptable TSA coatings is to create reliability and repeatability in processing with an effective quality control system.

The first step in establishing a quality control system for the TSA coating process is education. Within the organizational structure of a typical shipyard, interfacing with all trades during new construction or repair is complex enough without having to administer a new process (TSA) or include this process into a repair work scope.

Each trade, Planning Department, Quality Assurance (QA) Department, Safety Department, and Production Department should be familiar with the TSA coating process and how it will affect the components or areas they are responsible for. The quality of a TSA coating after being originally applied, can be jeopardized by mechanical damage from welding, cutting or handling. Each trade should have the knowledge to deal with areas or components that have been TSA coated. Another part of the educational process is the training of operators, inspectors and supervisors to understand how the TSA coating process acceptance criteria is achieved. The careful selection of personnel to accomplish this process requires operators to have the skills, discipline and commitment to produce consistent quality work. Each potential operator should be pre-interviewed and assessed to determine if they have the required skills and necessary characteristics.

Quality Requirements for Production

Many shipyards have designated production personnel to perform a majority of the quality checkpoints. The Quality Assurance Department validates and performs key checkpoints such as, surface preparation and coating thickness. Each shipyard should define the individuals or departments for the following inspection responsibilities.

<u>Receiving Inspection</u>

Ž Initiate control documents (shop traveler, Q A reports).

- Ensure components are disassembled properly.
- Identify areas not to be sprayed such as: dissimilar metals (ferrous only are sprayed), machined surfaces, weld zones, close tolerance fits, key ways and sliding surfaces.

<u>Masking Inspection</u>

- Ensure all areas not to be blasted or sprayed are properly and sufficiently protected using appropriate masking materials.

Anchor Tooth Blast Inspection

- Ensure all masking materials are intact.
- Ensure part has not been damaged by blasting.
- Ensure a clean white metal surface (SSPC-SP5).
- Ensure an anchor tooth profile of 2-3 mils (0.002-0.003 inches). Record results.

Pre-production Bend Test

- Verify and record anchor tooth profile.
- Verify and record coating thickness.
- Prepare, TSA coat, test and evaluate one bend test coupon for each operator per shift.
- Compliance of the bend test samples is required prior to production work.

Temperature and Humidity Requirements

- Measure and record ambient temperature.
- Measure and record relative humidity.
- Determine dew point.
- Measure and record component temperature, ensure component temperature is a minimum of 10 degrees F. above the dew point.

Coating Inspection

- Measure and record coating thickness (5 random areas).
- Ensure total coverage of the TSA coating.
- Visually inspect for any blisters, chips, cracks or surface contamination of the coating.
- Visually inspect using a 10X magnifying glass for nodules not exceeding the acceptance criteria.

Final Inspection

- Ensure parts have received proper sealer coat and paint system.
- **Ensure parts are properly packaged for transport.**
- Review records package for traceability **documentation.**

Facility Quality Assurance Requirements

Calibration System: Maintain all gases, flow/amp/voltage meters, measuring tools and testing equipment in current calibration in accordance with Mil-Std 45662A. These devices should have up to date calibration stickers showing the next and last calibration dates.

Air Quality check Periodically, (yearly at a minimum) have the quality of the air used to support the TSA process checked by a laboratory for compliance with DoD-STD 2138. This certification could be checked more frequently if there is doubt the dryer system is functioning adequately.

Operator Certification Maintenance: Establish a recall system to control each operator's TSA certification by reviewing their performance and coating production records. This will ensure they have met the minimum requirements of maintaining certifications.

Grit Qualitv Testi Set up a daily procedure to verify and record the condition of the grit used for anchor-tooth profile blasting. Refer to the sample in Appendix G.

Records

DoD-STD 2138 defines the record keeping requirements as follows:

Records of facility approval, application procedure, operator certification test results, and production records, shall be maintained by each performing activity, contractor or subcontractor. These records shall be available to the contracting agency for review and audit. The performing activity shall maintain these records for six months after completion of the contract work

Copies of the records shall be made available to the contracting agency upon request.

Operator Certification Test Sample Requirements (DoD-STD 2138)

To comply with the requirements for certification or recertification, each operator must prepare, TSA coat and test the following samples

Four Bend Test Coupons
Five Bond (Tensile) Test Samples
Two Shape Test (1 "T" and 1 Round)

Each of the above samples will be examined in accordance with the visual acceptance criteria. The bend test and the bond (tensile) test samples are required to meet the acceptance criteria for their respective tests.

Test Sample Sizes and Materials

Bend Test: 0.050" thick x 2" x 3" minimum, flat panel (mild steel) 4130 or equivalent

Tensile Test Coupons: 1" Diameter x 2" long material (mild steel) 4130 or equivalent

Shape Test Samples, "T": 1/2" thick, base 6" long x 3" wide, leg 3" high x 3" wide

Shape Test Sample, Round 1/4" wall thickness, 2" diameter x 6" long material (mild steel) 4130 or equivalent

TSA Coating Test Procedures and Acceptance Criteria

Tensile Test: Tensile tests are required at the time of operator qualification or requalification. Tensile test specimens shall be machined and prepared according to the requirements of ASTM C 633 and DoD-STD 2138. The acceptance criteria of the coating is a minimum tensile strength of 1500 psi and an average tensile strength of 2000 psi. Tensile tests shall be accomplished per ASTM C ***633.*** Fig. 7.1 shows typical failure modes for tensile test specimens.

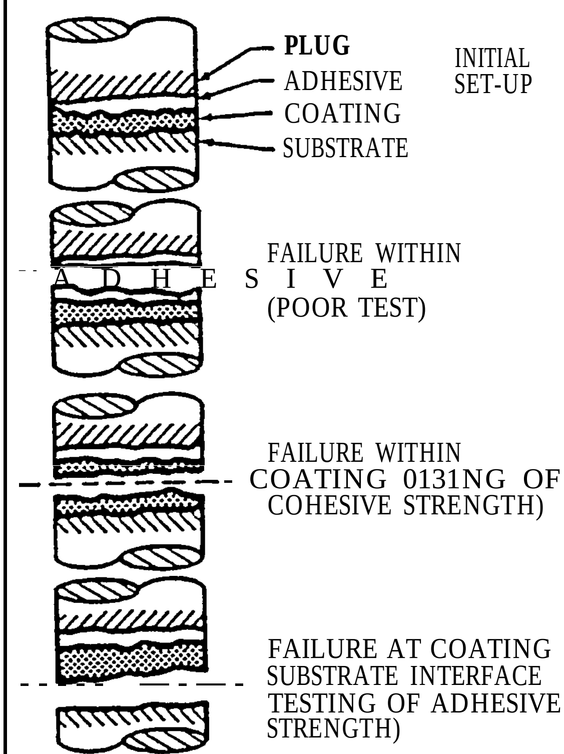


Fig. 7.1 Modes of Coating Failure

Bend Tests After preparing and applying the coating on one side of the bend test sample, insert sample with the coating on the outside into a bend test fixture and bend the sample 180 degrees around a 1/2" diameter mandrel. Visually examine the coating for disbanding or delamination caused by the bending. Small cracks and "alligatoring" of the coating in the vicinity of the bend are acceptable. Refer to Fig. 7.2 or Appendix H for acceptance criteria.

Visual Inspection Requirements: Each sample item should be examined visually at

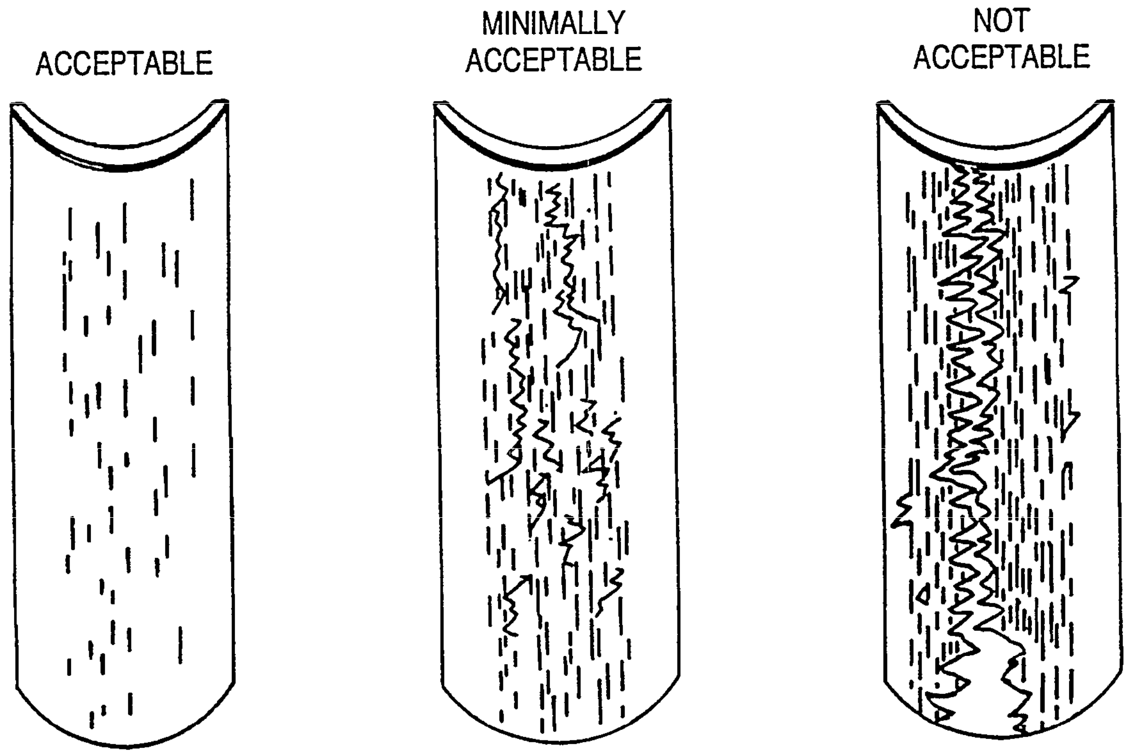


Fig. 7.2 Bend Test Samples

a magnification of 10X. The coatings should have a smooth, uniform appearance. The coating system should not contain any cracks, pin holes, or chips that expose the metal substrate. Surface defects of the TSA coating should be limited to small nodules not to exceed 0.045 inches in diameter, and should not exceed 0.025 inches in height above the surrounding sprayed surfaces. The coating should not contain any of the following:

- Blisters
- Cracks
- Chips or loosely-adhering particles
- Oil or other internal contaminants
- Pits exposing the undercoat or substrate

In the event of a suspected non-compliant coating application, a knife peel test or adhesion test can be used to determine if the coated area will meet the minimum acceptance requirements. The adhesion test is applicable only to interior wet spaces as defined in DoD-STD-2138 page 1 Para. 4.4.5, Category III. (See Appendix H.)

7.2 Coating Repair

Components being transported from the spraying area to the installation area must be handled carefully to avoid damaging the surface. Large items should be lashed to a pallet for shipment. Smaller items should be placed in boxes with the items wrapped or separated.

Extreme care must be exercised when installing or assembling the component. If small nicks or gouges are found, the item should be cleaned, resealed and top coat painted as soon as possible. Small nicks and gouges can be touched-up without harming the life of the coating. However, large dents in the aluminum coating will require removal of the damaged area and reapplication of the TSA coating and sealer.

Although the new revision of DoD-STD 2138 has not been officially released as of this writing, proposed new specification requirements to repair TSA coating systems are defined in Table 7-A.

SUBSTRATE NOT EXPOSED		SUBSTRATE EXPOSED	
SMALL AREA (<100 IN²)	LARGE AREA (>100 IN²)	ONLY PAINT TOUCH-UP REQUIRED	TSA COATING REPAIR REQUIRED
• Solvent clean as required. • Use a 1" flexible-blade paint scraper, and remove loose paint around worn or damaged area to the boundary or the well bonded paint. Take care not to gouge or further damage the TSA coating. • Use a stiff hand-held non-ferrous bristle brush and vigorously brush away loose debris. • Feather a 2-3" collar into the undamaged area. • Lightly abrade the feathered paint area around the exposed TSA coating with sand paper to provide a mechanical bonding surface for the paint primer and sealer.	• Solvent clean as required. • Abrasive brush blast away loose paint using aluminum-oxide grit over the exposed TSA coating area. • Feather a 2-3" collar into the well bonded paint area. • Minimize cosmetic difference between new and old paint by brush blasting or using sand paper and repainting as area bordered by a weld bead or a structural item.	• Solvent clean as required. • Using a paint scraper, push the blade underneath the TSA coating to lift off all loosely bonded TSA coating until reaching a well-bonded area. • Use portable disc sander with 80 mesh sandpaper and clean steel substrate to clean metal feathering 2-3" into the undamaged coated area.	• Solvent clean as required. • Abrasive blast area to be repaired with 16-30 mesh aluminum oxide to white metal to give a 2-3 mil anchor tooth. • Feather 2-3" into the good coating area. • Apply TSA coating as specified.

Table 7-A Proposed TSA Repair Procedures From Draft 2138(A)

In cases when areas have purposely been left unsprayed, such as weld zones, touch-up on these areas on-board ship may have to be accomplished. The ideal method for this procedure is as follows:

• When originally applying the TSA coating, mask the anticipated weld zone.

• Apply the TSA coating up to the masked area.

• Remask approximately 1 inch above the boarder of the TSA coating leaving a boarder of aluminum.

• Seal the TSA coating to the masked boarder.

• Install the component on board ship or on block.

• Remove the masking, and blast and TSA coat the unsprayed areas, using extreme caution when blasting on to the existing TSA coating.

- Reseal the newly applied TSA coating.

The reason for this procedure is to avoid sealing any area where additional TSA coatings are to be applied and to prevent contamination of the tie-in area where the new coating meets the old.

The reblasting of any TSA coating for the purpose of recoating or tying-in areas adjacent to those that have been previously coated requires a delicate technique. Blasting existing TSA coatings is not difficult, but it needs to be handled differently than when blasting uncoated surfaces. The TSA coating will tend to work harden under the high pressure and impact of normal blasting techniques. Reduced air pressures and faster, longer distance passes are necessary to avoid damage to the coating. Practice during the hands-on portion of the training will greatly enhance this technique.

Complete removal of an existing, properly applied TSA coating by grit blasting is a very difficult, time consuming process. It is best to use a smaller mesh size abrasive (60 - 80 grit) at an angle of approximately 15-20 degrees to peel the coating from the surface.

There are chemicals that can readily remove the aluminum if the component is small enough to be immersed within a tank. Prior to using any caustic chemicals for coating removal, check with the shipyard's metallurgist to ensure the chemical will not damage the base material. There is also a possibility of the chemicals being entrapped within welded or porous areas of the component, and when a new TSA coating is applied, the chemical could react with the coating and start to deteriorate the coating from the inside-out. Residual chemicals could be removed by high pressure water blasting, although high risk areas should not be stripped using chemicals without ensuring complete removal of the chemicals.

In cases where large areas of aluminum coating require removal, high pressure water jet blasting is a cost effective removal technique. An in-depth study was performed by Puget Sound Naval Shipyard, and can be obtained from NAVSEA Code 07011. (Also see Reference 1.)

8. SAFETY AND ENVIRONMENTAL

8. SAFETY AND ENVIRONMENTAL

This section discusses the potential safety and environmental hazards associated with thermal spraying, preparation and related finishing processes and presents safe practices applicable to those operations.

It is recommended that all personnel concerned with thermal spraying become familiar with these guidelines and the more extensive requirements contained in established standards. (See Appendix C for a list of standards.) Often when handling toxic materials, Federal (OSHA Standards), state and local requirements exist and these should be determined and complied with. Disposal of toxic materials generated by the thermal spraying process or subsequent finishing operations must comply with the EPA's Resource Conservation and Recovery Act (RCRA), as well as state and local regulations governing the disposal of hazardous wastes. All hazardous waste should be sent to a regulated hazardous waste treatment and disposal facility.

Fire Protection

The basic precautions for thermal spraying are essentially the same as for welding and cutting. Consult Safety in Welding and Cutting, ANSI Z49.9, Standard for Fire Prevention in Use of Cutting and Welding Processes, NFPA 51B, and the Standard for the Storage and Handling of Liquefied Petroleum Gases, NFPA 58.

Airborne, finely divided solids or accumulations of such, especially metal dusts, should be treated as explosives. To minimize danger from dust explosions, adequate ventilation should be provided to spray booths. A wet collector of the water wash type is recommended to collect the spray dust. Bag or filter-type collectors can be used only after consultation with those experienced and knowledgeable in the field.

Sludge from wet collectors should be disposed of using methods that apply to this type of waste.

Good housekeeping in the work area should be maintained to avoid accumulation of metal dusts, with particular attention given to inspecting for dust on rafters, tops of booths, and in floor cracks. The extremely hot condition of thermal spraying operations requires additional precautions such as, not pointing thermal spraying equipment that is in operation at any person or at material that will burn.

Certain hydrocarbon decreasing solvents and sealer bases are flammable, toxic and carcinogenic, and special handling precautions need to be exercised relative to their use, handling and storage, in and about the thermal spray area. Paper, wood, oily rags, or cleaning solvents can cause fire and should not be stored or contained within the spray areas.

Storage and Handling of Compressed Gas Cylinders

Local, state, municipal, and Federal regulations relative to the storage of cylinders should be investigated and complied with. Storage, handling and use of oxygen and all fuel-gas cylinders should be in accordance with *Safety in Welding and Cutting, ANSI Z49.1,* and with *Safe Handling of Compressed Gases,* CGA Pamphlet P-1.

Oil or grease on oxygen equipment can be extremely dangerous due to explosive hazard. Only special oxidation-resistant lubricants may be used with oxygen equipment. When in doubt, consult a qualified dealer or the equipment manufacturer.

Manifolding of cylinders is frequently required in thermal spraying work These instances should be in accordance with

ANSI Z49.1. Pressure reducing regulators should be installed and used in accordance with ANSI Z49.1. Use only the appropriate regulator for each gas cylinder.

Flow meters should be installed and used in accordance with ANSI Z49.1. If a flow meter with glass tubes is used, a protective shield should be placed between the flow meter and the gun. Also, back flow preventive devices should be used together with flow meters to avoid unsafe operating conditions and to ensure proper flame balance.

Hose and hose connections should be installed and used in accordance with ANSI Z49.1 and Specification for Rubber Welding Hose, published jointly by the Rubber Manufactures Association and the Compressed Gas Association. Avoid damage to hoses. Use hoses only for the purpose for which they were designed.

Compressed air should be referred to by its proper name to avoid confusing it with oxygen or fuel gas. Air, oxygen or fuel gas should not be used to clean clothing. Use compressed air for thermal spraying or blasting operations only at pressures recommended by the equipment manufacturers.

Thermal Spray Equipment

Thermal spray guns should be maintained in accordance with the manufacturer's recommendations. Each thermal spray operator should be fadiar with the operation of the gun and should read the instruction manual thoroughly before using it. Use an approved friction lighter, a pilot light or arc ignition for lighting flame spray guns. When a gun has backfired, shut it off as quickly as possible. Reignite a gun only after first checking the unit for the cause of the trouble. When spraying is terminated, the equipment shut down, Ieft unattended, or taken down, release all gas pressure from the regulators and hoses.

When cleaning thermal spray guns, any oil used that enters the gas mixing chambers could result in an explosion when relighting the gun. Avoid the use of ordinary oils or greases for lubricating the valves or other part of a gun that are in contact with oxygen or fuel gases. Use only special oxidation resistant lubricants recommended by the equipment manufacturers.

Abrasive Blast Machines

Abrasive blasting machines should be maintained and inspected according to the equipment manufacturer's recommendations. Worn parts should be removed and repaired or new parts (as recommended by the manufacturer) installed. Spent abrasive blast materiai may be hazardous waste and should be tested before disposal

Blast hoses should be as straight as possible between the blast machine and blasting area. Sharp bends in the hose will cause excessive friction and wear possibIy resulting in a blowout at those areas. If a hose must be curved around an object, use long radius curves.

Air pressure in a blast tank should not exceed the pressure recommended by the supplier. BIast hose controls should be such that continuous pressure on the activating lever by the operator is required; when such pressure is released, the equipment shuts off (dead man control). A blast nozzle pointed at any part of the body may result in serious injury.

Most blasting operations require that the operator is provided with some form of respiratory protective device. The selection, operation, and maintenance of this device should be in accordance with ANSI Z88.2.

Protection of Personnel

The general requirements for the protection of thermal spray operators are the same as

for welders, as set forth in Safety in Welding and Cutting, ANSI Z49.1, Standard Practices for Occupational and Educational Eye and Face Protection, ANSI Z87.1, Standard Practices for Respiratory Protection, ANSI Z88.2, and Standard Practices for Industrial Head Protection with Low Voltage Hazards, ANSI Z89.1.

Helmets, hand shields, face shields, or goggles should be used to protect the eyes during all thermal spraying or blasting operation. These are described in ANSI Z87.1, and Z89.2. It is necessary for thermal sprayers or blasters to use goggles at all times for protection against flying particles from adjacent operations. All attendants or helpers should be provided with proper eye protection. While thermal spraying in the open, where ventilation is adequate to eliminate the need for additional respiratory protection, goggles only may be worn. The goggles should have indirect ventilating fins to eliminate danger from flying particles and to reduce fogging.

Most thermal spraying and blasting operations require that respiratory protective devices be supplied to the thermal spray operator or blaster. The nature, type, and magnitude of the fumes and gas evolved determine that respiratory protection device should be used. The selection of these devices should be in accordance with ANSI Z88,2. This standard contains description, limitations, operational procedures and maintenance requirements for standard respiratory protective devices. All devices selected should be of a type approved by the U.S. Bureau of Mines, NIOSH, or other approved authority for the purpose intended. While the selection of these devices should follow the guidelines of ANSI Z88.2, those listed below are suggested for typical thermal spraying and blasting operation.

For blasting in the open, a mechanical-filter respirator should be used in conjunction with the face shields and dust hoods. Alternately, an air line respirator may be used. For blasting in confined or semi-confined spaces, a continuous flow air line respirator for abrasive blasting should be used. This consists of a standard continuous flow air line respirator whose full face piece or helmet and dust hood have been reinforced to protect the wearer's head and neck from rebounding abrasive. The respirator should allow at least 4 cubic feet of air per minute to enter the face-piece, and at least 6 cubic feet of air per minute to enter the helmet hood.

An in-line vortex cooler should be used when possible for operator comfort. The air supply line should contain a suitable filter to remove objectionable odors, oil and water mist and rust particles from the air generated by the compressor blower. Care should be exercised in situating the air intake to ensure that the air supplied to the respirator is not contaminated. The air supply line filter will not provide protection against gaseous contaminants such as carbon monoxide unless a separate air purifier is used to assure respirable air.

For thermal spraying in the open, additional respiratory protection may not be necessary. In borderline cases, such as for light thermal spraying work of short duration with non-toxic materials and with dust exposure only, approved mechanical filter respirators for protection against dusts and metal fumes should be used. These are fitted with filter pads (and flutter valves) to remove dust.

For thermal spraying in confined or semi-confined spaces, an airline respirator should be used. This is of the same design as the abrasive blasting air line respirator, except that it need not be reinforced on the helmet, face piece or hood for protection against rebounding abrasive. For this reason, an abrasive blasting continuous flow air line respirator may be used for both thermal spraying and blasting in confined or semi-confined spaces.

Individual respiratory protective devices should be well-maintained. They should not be transferred from one employee to another without being cleaned and disinfected. (For methods of cleansing and disinfecting, consulk ANSI Z88.2)

The thermal spraying processes may generate excessive noise levels. It is mandatory to limit employee exposure to excessive noise within the limits of federally recognized standards as prescribed under the Occupational Safety and Health Act (OSHA). All personnel in the vicinity of thermal spraying should be provided with protection for the ears if the noise exposure exceeds the limitations established in paragraph 1910.95 entitled “Occupational Noise Exposure” of the Occupational Safety and Health Standards of the Department of Labor. Refer to Tables 8-A and 8-B for noise levels and durations.

EQUIPMENT	SET-UP	E L“xL?A2
Arc Guns	24 volts/200 amps	111
	32 volts/500 amps	116
Powder Guns - Normal	Acetylene - WIO spray booth	89
	WI spray booth and air jet cooling	110
- High Capacity	Acetylene - WI spray booth	94
	WI spray booth and air jet cOoling	111
Wire Combustion Guns 1/8 in. and 3/16 in. wire	Acetylene	114
	Propane	118
	Propane and nonload hardware	125
	Methylacetylene-propadiene gas	118
Typical Griiblasting Equipment		80-85
Typical Exhaust Equipment		less than 90

Table 8-A Typical Noise Levels for Thermal Spraying Equipment

Appropriate protective clothing required for any thermal spraying or blasting operation will vary with the size, nature, and location of the work to be performed. Clothing should be strapped tightly around the wrists and ankles to keep dusts from sprayed materials and abrasives away from the skin.

Working in Confined Areas

As used herein, “confined spaces” is intended to mean a restricted space such as a closed tank, boiler, pressure vessel, or compartment of a ship. If the confined space has previously held combustible materials it should be rendered safe for work before entering.

Ventilation is a pre-requisite to work in confined spaces. When thermal spraying is being performed in any confined space, the gas cylinders should remain external to the space. Where a thermal spray or grit blast operator must enter a confined space through a manhole or other small opening, means shall be provided for quickly exiting in the event of emergency. When safety belts and life lines are used for this purpose, they should be attached to the workman’s body so that he cannot be jammed in a small exit opening. At least one attendant trained in rescue work should be stationed outside at all times and proof of his ability to remove the person from the confined space should be demonstrated before the operation begins.

To eliminate the possibility of gas escaping through leaks or improperly closed valves, the gun valve should be closed and the gas supply to the gun positively shut off at a point outside the confined area. This is espeaally important when the gun is not to be used for a substantial period of time, such as during lunch or overnight. Where practicaI, the gun and hose shouId be removed from the confined space. In some cases, an oxygen deficiency in the confined space should be evaluated.

dBA		Hr/DAY
90		8
92		6
95		4
97		3
100		2
102		1.5
105		1
110		0.5
115		0.25 or less

Table 8-B Allowable Noise Level Duration

Ventilation

When ventilating confined spaces, all air replacing that withdrawn should be clean and respirable. Fans should be sized to give at least ten air changes per minute. If portable gasoline or diesel engine driven ventilators or compressors are used, they should be located so that engine exhaust gases cannot be drawn into the ventilating system. This measure also will prevent exhaust gases from entering the intake of the compressor. This is particularly critical if the air is to be used for respirators.

There are many factors that determine the amount of contamination to which the workman may be exposed when blasting and thermal spraying, they include

- Volume of space in which the thermal spraying is to be done.

- Number of thermal spray and grit blast operators.

- The evolution of hazardous fumes, gases, or dusts according to the abrasive used or material being sprayed.

- Heat generated by the spraying process.

- Presence of volatile solvents.

All of the preceding should be considered to better protect the health of the operators and to supply ventilation to any thermal spraying application. Local exhaust or general ventilation systems should be provided to control toxic fumes, gases, or dusts and their removal from the work area.

The ventilation equipment for most field thermal spraying and blasting operations consists of engine or motor driven portable exhausters with flexible piping or ducts arranged to remove dust as rapidly as possible. This allows the operators to have suitable visibility. However, no system of this type will ever be perfect, and it will therefore be necessary for the operators to wear respiratory devices. When exhausting dust with portable exhausters, it may be necessary to attach a dust collector (such as a bag filter) to the exhauster to trap the dust and prevent contamination of the surrounding area. Dust from dust collectors may be hazardous waste and should be tested before disposal.

Spray cabinets used for spraying small and medium size parts should be equipped with exhaust ventilation with an air veloaty of 200 to 400 feet per inch entering the hood. The spray equipment should be operated within the face area of the hood and directed into it.

Blasting rooms should be designed to be well-lighted, and adequately ventilated. Ventilation should be provided so that the down draft and longitudinal ventilation will have a velocity of 50 to 100 feet per minute. The blasting room should be equipped with a dust-collecting system. This is usually required by local law ordinances. Further, local, state, and federal regulations should be investigated before exhausting directly into the atmosphere.

If dust collectors are used, closed-type collectors should be provided with blow-out holes or relief panels. Blow-out panels should be provided in ventilation piping. All fans, pipes, dust arresters, and motors should be attached to an acceptable earth ground.

Ventilation fans should be kept running when cleaning out booths, pipes, etc. This prevents the accumulation of dust or fumes in the system. Aluminum dusts present an explosive hazard that requires special attention. Adequate wet collector systems should be used. Care must be exercised as these metallic dusts in water may generate hydrogen gas. These systems should be designed to prevent hydrogen accumulation anywhere in the system. Frequent clean out operations should be performed to reduce residues. No welding or cutting should be done in the repair of any ventilation or dust collecting equipment unless the equipment has been thoroughly cleansed.

All materials, in finely divided form, (toxic) may be damaging to the respiratory system, and the precautions necessary for protecting the health of spray operators vary according to the type material being sprayed. Careful attention to this health problem is particularly important because the damage does not cause an immediate sensory effect. In addition to respiratory requirements, extreme care should be taken to keep floors, work benches, and booths free from dusty residues for optimum health protection. Used clothing should be properly processed **to** remove dusts or be discarded.

Special precautions should be taken when spraying materials that have been vapor degreased to see that all the solvent has been removed prior to thermal spray coating. Avoid liquid films or drops of solvent caught by pockets and crevices. Vapors from these solvents should not be present in the spraying area.

Threshold Limit Values

Threshold limit values are for air concentrations of hazardous materials with exposures not exceeding a total of eight hours daily. Threshold limit values (TLV) were adopted by the American Conference of Governmental Industrial Hygienists L4CGIH). These values are published annually under the title “Threshold Limit Values, Recommended and Tentative” by the ACGIH, at which time they are reviewed and additions or revisions made. An up-to-date list of the TLV’S should be consulted concerning the maximum allowable concentration of toxic material that may be encountered. Maximum threshold limit values are also published by the American National Standards Institute in Standards Series Z37 “Allowable Concentration of Toxic Dust and Gases.” The above sources should be consulted as standards are subject to change.

When possible, air sampling should be conducted to determine the ventilation requirements for operations involving the above metal and / or solvents. When other less toxic metals are sprayed, the concentration of dust or fumes in the work area should never exceed the TLV for eight hour exposure. Respiratory protective devices and exhaust ventilation should be provided when the dust or fume concentration is sufficiently high to cause operator discomfort even when the appropriate TLV is not exceeded.

Safety Standards

Mandatory Federal Safety Regulations have been established by the Occupational Safety and Health Administration (OSHA). For information on these regulations, refer to OSHA Standards, Code of Federal Regulations, Title 29, Part 1910, available from the Superintendent of Documents, Government Printing Office, Washington, DC 20402.

One of the principal safety hazards of the thermal spraying process is the handling of compressed gases. The safe handling of compressed gases is covered by reference to the complete treatment of the subject in the American National Standard, Safety in Welding and Cutting, ANSI 249.1, available from the American Welding Society and in accordance with the Williarns-Steiger Occupational Safety and Health Act of 1970 (84 Stat. 1943). More recently, the newly enacted Resource Conservation and Recovery Act (RCRA), dealing with the disposal of toxic wastes, has a potential for additional impact upon this industry and requires consultation as that legislation is clarified. Refer to Appendix C for a complete listing of safety standards.

9. ECONOMICS

9. ECONOMICS

9.1 Facilities and Equipment Descriptions and Costs

The costs associated with the application of a thermal sprayed aluminum (TSA) coating are based on many variables. This section provides general guidelines regarding costs of equipment and processing, including rates for preparation, blasting, TSA coating application and sealing (painting operation). The types of equipment described in this section include compressors, air dryers, abrasive blasters, dust collectors, safety devices, quality assurance items and paint systems used to support both stationary and portable TSA facilities. Depending on the facilities internal structure, some of these costs will be amortized through capital appropriations or they may be part of the normal overhead costs. This section will identify elements that make up the direct and indirect costs associated with a TSA coating program.

Facilities

The extent of the required facilities depends on the scope of work to be accomplished. The cost of facilities would have to be determined based on size and geographical location. In planning for the facilities, it is important to use a modular concept looking toward future growth. A major pitfall in new installations is lack of long range planning for expansion and new related technologies.

The basic facility requirement is a structure to house equipment to prepare, abrasively blast, TSA coat and finish paint components. The facility utility requirements are air, water and electricity to support the equipment necessary to apply TSA coatings. Supplemental heating or air conditioning may be an additional requirement. Humidity may present an additional problem for processing, so dehumidifying the facility should be considered. Facility space also must be allocated for offices, storage of components, spare parts and consumables.

Permanent facility installations require advanced planning and capital appropriations that may take considerable time to acquire. Many shipyards have elected to use a unique facilities concept developed by a San Diego company (Flame Spray, Inc.) They have designed and built custom turn-key Thermal Spray Containerized Systems for many shipyards. These hum-key facilities, which are housed in 8’ x 8’ x 20’ cargo containers, are modular in concept. They can be constructed for use as single or multiple units for creating additional work areas as large as required. (Turn-key is described as having all necessary electrical, mechanical, structuaral, sound attenuation, air scrubbers and safety equipment for a complete custom designed thermal spray facility.) Units can be built to house systems ranging from hand-held combustion type spray units to arc plasma spray systems with computerized robotics. (See Appendix F for typical floor plan of modular TSA facility.)

The following general equipments can be included in the containerized system to process a variety of components

- Compressed Air / Air Dryers
  Portable compressors, electric or diesel; Regenerative type air dryers with aftercooler; oil coalescing, and after filters, 150-900 cfm capacities

- Abrasive Blast Systems
  Air swept rooms with reclaimers and dust collectors; Blast cabinets with reclaimer and dust collectors

- Thermal Spray Systems
  Combustion, wire and powder; Electric arc wire systems

- Environmental Control Devices
  Water wash booths; Dry collection systems

- Handling Equipment
  Overhead and jib cranes; Tilting turntables; Head stock, tail stock, rotating assemblies; Horizontal/ vertical gun traverse devices; Robotics

- Sound Attenuation
  Enclosures are designed for a maximum dBA level of 84 outside the units.

- Utilities
  Power, single source 440 volt, 3 ph; Air, 250 cfm at 100 psi minimum

- Safety
  Each unit is designed to comply with safety requirements of eye protection, air movement, sound attenuation, fire codes, electrical codes, and safety interlocks.

- Costs
  Units can be purchased at a base price of $145,000.00* (2 units; Blast and Spray), leased with a purchase option, or rented, depending on the shipyard's requirements.

*FSI 1991 pricing, F.O.B. San Diego, CA.

The following equipment is required to support a thermal spray facility:

Compressed Air

Compression of air has one basic goal, to deliver air at a pressure and volume suitable to operate various components needed for thermal spraying and complementary equipment. There are three types of compressors to consider in the selection of a system Reciprocating, Vane Type Rotary and Twin Screw Helical Lobe.

Compressor size and type will depend on the number of blast nozzles and other air-using equipment. Normally 250 cfm at 125 psi is considered minimum. For any work on board ship or in remote areas where compressed air of the required volume and pressure cannot be dedicated, a portable compressor is used. The air volume required will be dictated by the number of blast nozzles and other air consuming equipment used on site. These compressors can be fuel type or electrical (if there is power available). Table 9-A compares the costs for various types of compressors.

EQUIPMENT TYPE	APPROXIMATE UNIT COST	OPERATION COST	MAINTENANCE COST
Reciprocating	$39,000.00	$4.50/hr.	$ 700.00/yr.
Rotary	$13,500.00	$4,50/hr.	$ 850.00/yr.
Twin Screw	$16,500.00	$3.60/hr.	$ 750.00/yr.
Portable	$19,500.00	$4.75/hr.	$1,500.00/yr.

Table 9-A Compressor Cost Summary

Models Used for Cost Comparison in Table 9-A:

EQUIPMENT TYPE	MANUFACTURER/MODEL
Reciprocating	Ingersoll-Rand Type 40-875 Air Cooled Reciprocating Compressor, 268 cfm, 75 HP
Rotary	Compair Kellogg Sliding Rotary Vane Compressor Model 258, 235 cfm, 60 HP
Twin Screw	Ingersoll-Rand EP60S/S Air Cooled Twin Rotary Screw Compressor, 241 cfm, 60 HP
Portable	Ingersoll-Rand Model P250WD Deutz Diesel, 250 cfm

Compressor costs are based on 1991 Ingersoll-Rand published prices. Electrical operating costs are based on current San Diego rates. Since other manufacturers may have a different cost basis, each shipyard should verify all costs prior to implementing a TSA coating program.

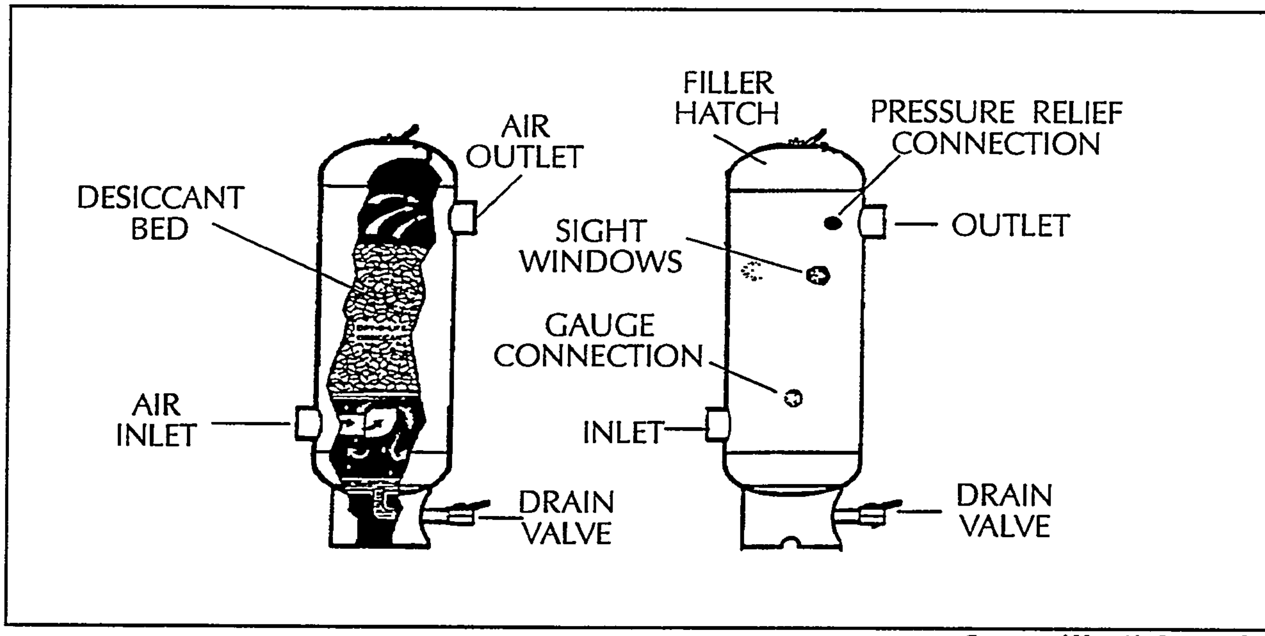
Air Drying Equipment

Clean, dry air is used for grit blasting and air cooling during and after spraying, in addition to the operation of thermal spray equipment. Many contaminants, such as water vapor, oil mist and dust can be introduced to the air supply. Dirty shop air contributes to interface contamination, poor bond strength, flaking, spalling, cracking, interlamellar oxides and other defects of TSA coatings.

DoD-STD 2138 specifies clean, dry air for all processing (blasting and TSA coating). There are three basic types of dryers that meet the requirements of the specification: deliquescent, refrigerated and regenerative. It is important to size any air dryer to meet the total air consumption required for all equipments to support the TSA system.

Deliquescent Dryers Air drying with a deliquescent dryer is achieved in a single vessel. This system is engineered to direct a slow, even flow that exposes all the air to the deliquescent action of the desiccant. Wet air from the compressor enters the centrally located inlet which channels flow into the lower portion of the dryer. Air velocity is reduced and direction of flow is changed as the air strikes a diffuser plate. Heavier drops of liquid and some solid particles are separated and fall into the claim area.

As air moves through the desiccant bed in a slow scrubbing action, moisture vapor from the air is absorbed on the surface of the tablets. Droplets of dissolved desiccant and water are formed and eventually fall into the condensate claim area. At the dryer outlet, the air resumes its original velocity. Differential across the vessel is usually less than one percent of the operating pressure at rated capacity. Water has been removed from the air and the dry condition insures top performance of air-operated equipment.



Courtesy of Van Air Systems, Inc.

Fig. 9.1 Deliquescent Dryer

Refrigerated Dryers In the compressed air circuit of the refrigerated air dryer, wet air enters the shell side of the air-to-air heat exchanger for initial cooling the refrigerated, outgoing air. Pre-cooling the air increases energy efficiency of the dryer. The pre-cooled air then flows into the shell of the air-to-refrigerant heat exchanger. The final temperature reduction occurs as more heat transfers to the cold refrigerant in the tubes. As the air passes through the moisture separator, condensation is removed and discharged through an automatic drain valve. Air then returns to the tube side of the air-to-air heat exchanger. There, it is reheated before entering the plant air lines.

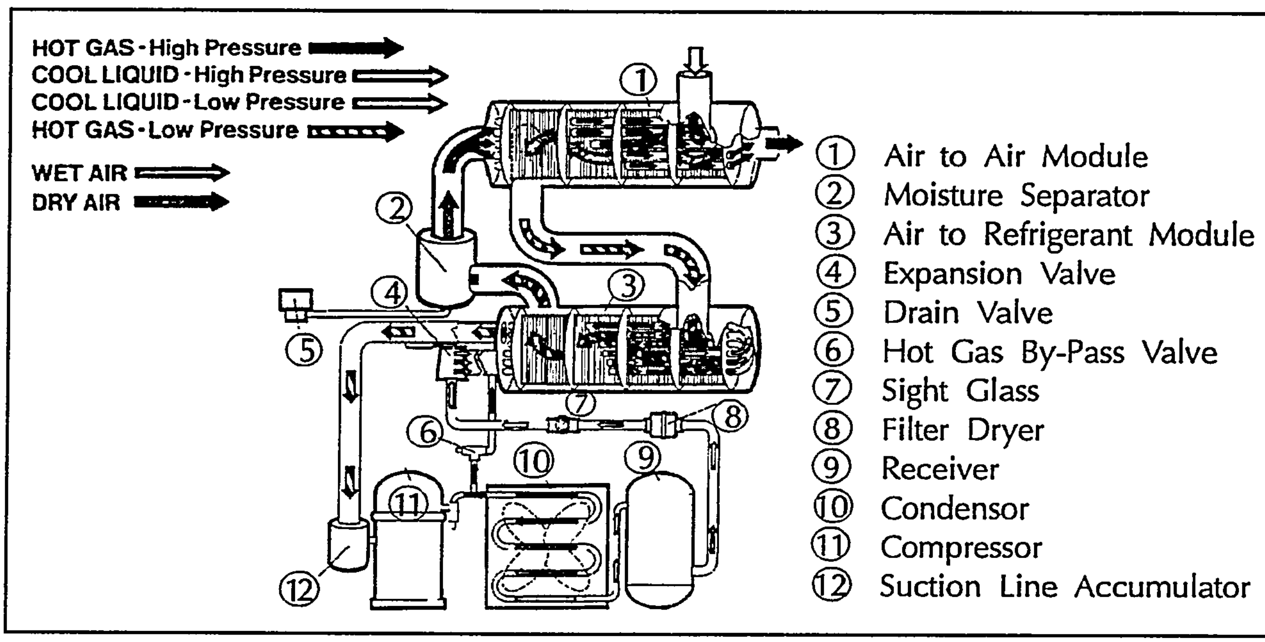


Fig. 9.2 Refrigerated Dryer

Courtesy of Van Air Systems, Inc.

Regenerative Dryers The regenerative, heatless dryers employ the pressure swing principle in twin towers filled with adsorbent desiccant. The self-contained process, which uses a purge of dry air for regeneration, requires no external source of heat. During an operating cycle wet inlet air to the drying tower flows upward through the desiccant bed where moisture is attracted to and adsorbed on the desiccant. A portion of the dry outlet air is diverted to the wet tower to regenerate the desiccant. As the dry purge air at atmospheric pressure flows downward through the tower, it collects moisture from the desiccant. The wet purge air is discharged through the purge valve and muffler. After a short interval, the tower operation changes automatically, and wet inlet air flows to the tower are regenerated. Regenerative dryers are designed for rugged duty, trouble-free operation and ease of maintenance.

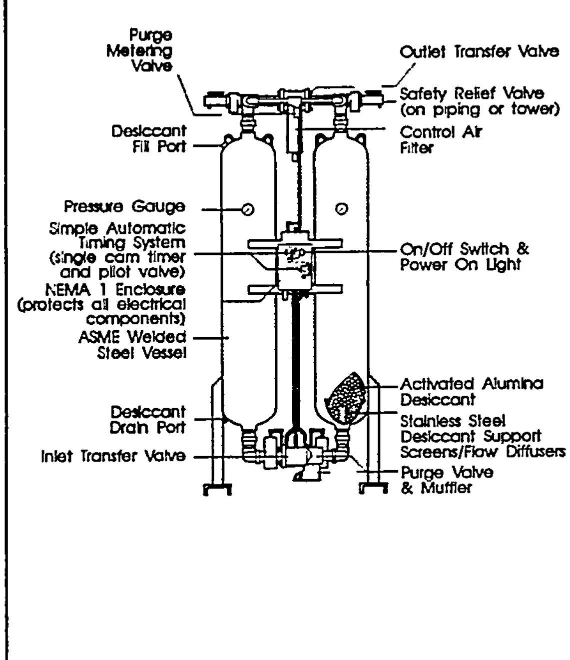


Fig. 9.3 Regenerative Dryer

Courtesy of Van Air Systems, Inc.

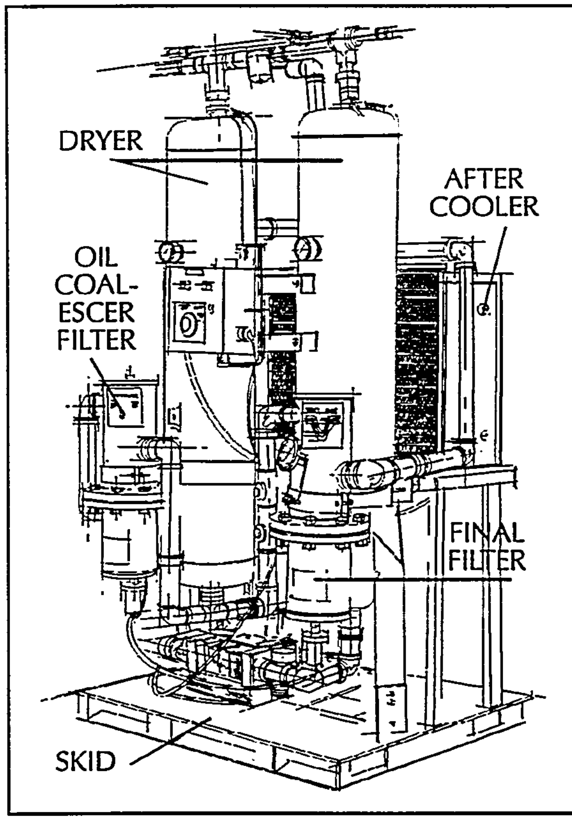


Fig. 9.4 Typical Air Drying System (Regenerative Dryer)

A compressed air drying system should include the following support equipments:

- Dryer
- After Cooler
- Water Trap Separator
- Oil Coalescer Filter
- Final Filter
- Auto Drain

Comparison Summary of Air Dryer Systems

As stated, all three types of dryers will meet the air quality requirements of DOD-STD 2138. To make a final decision on what type of dryer to install, each shipyard should use the following guidelines.

Of the three drying systems, the acquisition cost for deliquescent system is the lowest, refrigerant the second, and regenerative the highest priced of the three. Deliquescent

dryers require more service time than the other systems due to replenishment of the desiccant. Overall maintenance on these dryers is very low due to the simplicity of their design and operation. The daily service time for refrigerated and regenerative dryers is virtually non existent.

Maintenance of the refrigerated dryers or replacement of motors, fans, compressors, freon and switches can be very time consuming and costly. Refrigerated dryers do not readily lend themselves to portability and they do not function well where they are exposed to cold temperatures (32 degrees F. or lower). To accomplish on-site work, dryer portability is essential. The regenerative and deliquescent systems are most practical for on-site work.

Maintenance of regenerative dryers and replacement of the desiccant is required very infrequently (every 12 -18 months) depending on the compressed air quality. These systems are extremely reliable and trouble-free. These dryers require approximately 10 - 15 % of their rated cfm's to purge and clean the desiccant bed.

Electrical power is required for the refrigerated (220 volt or 440 volt, 3 Ph) and regenerative (110 volt) systems. There is no power required for the deliquescent system.

For supporting a TSA shop facility and portable TSA units, the deliquescent or regenerative type dryers are the preferable systems. For shipyards that do not wish to replenish desiccant frequently, the dryer of choice is the regenerative type.

EQUIPMENT TYPE	APPROXIMATE UNIT COST	OPERATION COST	MAINTENANCE COST
Deliquescent	$ 3,700.00	$ 0.01/hr	$ 1,000.00/yr
Regenerative	$ 6,500.00	$ 0.05/hr	$ 500.00/yr
Refrigerated	$ 5,000.00	$ 0.10/hr	$ 500.00/yr

Table 9-B Air Dryer Cost Summary

Models Used for Cost Comparison in Table 9-B:

EQUIPMENT TYPE	MANUFACTURER/MODEL
Deliquescent	Sahara Model #HP-275
Regenerative	Van Air Model #HL-350
Refrigerated	Ingersoll-Rand Model #HG-281

EQUIPMENT TYPE	APPROXIMATE UNIT COST	OPERATION COST	MAINTENANCE COST
Aftercooler	$ 1,500.00	$ 0.10/hr	$ 50.00/yr
Oil Filters	$ 375.00	N/A	$ 225.00/yr
Water Trap	$ 275.00	N/A	$ 50.00/yr
Auto Drains	$ 175.00	$ 0.01/hr	$ 25.00/yr

Table 9-C Air Dryer Support Equipment Cost Summary

All costs are based on 1991 manufacturers price lists. Current San Diego electrical rates are 0.10 per Kilowatt Hour. Other manufacturers may have a slightly different cost basis.

Models Used for Cost Comparisons in Table 9-C:

EQUIPMENT TYPE	MANUFACTURER/MODEL
Aftercooler	Van Air Model #TC-230
Oil Filters	Van Air Model #CL-300, KO-400
Water Trap	Clark Reliance Separator Model #CR-536
Auto Drains	Van Air SpitFire Model #SDV

Grit Blast Equipment

The function of abrasive blasting equipment is to produce a surface receptive for the thermal spray aluminum coating. This is accomplished by cleaning and roughening the surface. Blasting equipment is available in sizes ranging from hand held guns with a self contained grit canister to large, totally enclosed, fully automated systems. Primary considerations in selecting blasting equipment are productivity, ability to maintain clean and properly sized grit, and operator comfort. Reproducability of results and the protection of the operator and the surrounding area from environmental hazards are primary goals. Another consideration is the efficient usage of the blasting materials.

The type, size and degree of automation of any system should be tailored to the component or job, environmental standards and abrasive usage requirements. Blasting should always be performed in an enclosure designed for that purpose, and equipped with exhaust and dust collection facilities. Blast room designs vary with the application. To facilitate visibility and safety, all rooms should be equipped with an exhaust system to draw dust and contaminated material from the part and operator. Room dimensions depend on the size of the parts to be blasted.

Abrasive recycling varies from manual shoveling to fully automated systems. In automated self-contained systems, the abrasive falls through a grated floor to either a vibratory plate or a conveyor which trans-

fers it via an elevator to a holding area where it is cleaned. This transfer can also be a pneumatic system (air swept floor). Cleaning includes rescreening, sizing and dust removal. Fines are removed and reusable material is returned to the blasting tank.

Blast Generators

Manual blasting machines are available in two types: pressure and suction. Pressure type blasting machines are applicable to large work requiring high production rates. They are more effective and efficient than other systems, since higher velocities are imparted to the abrasive, to afford greater cutting action. Pressure machines use a "Blast Generator" consisting of a closed hopper for the abrasive, a carrier base, and a blasting nozzle. The generator is pressurized and the abrasive is carried through the hose and nozzle to the work piece.

Suction type blast cabinets are convenient and versatile for preparing a large variety of components. The abrasive medium is dispensed from a hopper at the cabinet base and air propelled to the substrate. The grit drops through a grate, returns to the hopper and is recycled. Reuse continues until the abrasive loses its effectiveness. Suction type machines range from small, manually operated units to intermediate sized and fully automated systems. They can be used with almost any type of abrasive. Enclosure size and system effiaency are limiting factors.

Blast Nozzles

Straight nozzles are commonly used for blasting. There are many sizes (diameters), lengths and configurations. Nozzle life depends on many factors including air pressure and type of abrasive. Inexpensive, short life, or expendable nozzles are manufactured from either cast iron or ceramic. Long wear nozzles are carbide or a carbide base composition. They are inserted into a steel or aluminum mounting that protects their hard, brittle, inner core. The internal configurating and length governs the type of blast pattern received at a given distance. Long wear nozzles may give up to 100 times the life of a conventional ceramic or iron nozzle, but are subject to breakage if not handled properly. Angle nozzles are made from carbide or carbide composition. The offset degree angle is designed for a specific application. They are manufactured with 15, 45 and 90 degree angles.

Portable Grit Blast Equipment

A well designed system to accomplish on-site blasting, recovery of abrasives, dust collection and temporary enclosures will greatly improve the productivity of the on-site work Each facility should be aware of the local regulations regarding abrasive blasting in the open. Many states have very stringent EPA requirements defining the control of spent abrasives and dust emissions from abrasive blasting. The system should be designed with these regulations in mind.

A portable system should include the following basic equipment

- Abrasive Blast Generator
- Recovery System (Electric or Pneumatic)
- Dust Collector
- Portable Enclosures for Grit Containment
- Hoses and Ducting
- All Safety Equipment

A grit reclaimer/separator is an option that many facilities incorporate in their remote and stationary facilities. This device separates the reusable abrasive from the fines and other materials.

Portable Blast and Spray System

Many shipyards are required to apply a TSA coating system on-block or on-board ship. The equipment required to accomplish this remote work is much the same as for in-shop work. The major difference is that all of the equipment should be able to be easily moved from point to point, and operators should have all the support equipment and tools to quickly and efficiently set up and accomplish the work.

Portable work stations have been developed incorporating a skid design (tool and equipment platform) concept that conveniently and efficiently houses all necessary equipments to prepare and apply TSA coating for remote on-site work. The skid concept is a multi-platform design. These skids house the abrasive blasting and dust collectors, the spray equipment, air dryer and bottle storage. All required equipment and storage are provided to accomplish work on-site. They can be moved by forklift or crane to within 300 feet of the work area. Hoses, ducting and hand-carried equipment can be run from the skids to the work area.

The following equipment is included in the portable system:

- Blast Generator (12 cu ft capacity)
- Reclaimer/Recovery System
- TSA Equipment (Guns, Wire, etc.)
- Hoses and Ducting
- Vacuum System
- Dust Collector
- Air Dryer
- Safety Equipment

EQUIPMENT TYPE	APPROXIMATE UNIT COST	OPERATION COST	MAINTENANCE COST
Blast Room	$ 67,000.00	$ 0.50/hr	$1,500.00/yr
Dust Collector	$ 14,000.00	$ 0.50/hr	$ 500.00/yr
Recovery System	$ 25,000.00	$ 1.50/hr	$1,500.00/yr
Blast Generator	$ 4,230.00	use air only	$ 500.00/yr
Blast Cabinet	$ 7,650.00	$ 0.30/hr	$ 350.00/yr
Blast Nozzle	$ 125.00	N/A	replace every 80 hours
Portable Skid	$ 87,000.00	$ 2.60/hr	$1,500.00/yr

Table 9-D Blasting Equipment and Portable System Costs

Models Used for Cost Comparisons in Table 9-D:

EQUIPMENT TYPE	MANUFACTURER/MODEL
Blast Room	Zero Model #14-225. 10' Wide x 20' Long x 10' High. Including Dust Collector, Blast Pot, Hoses, Safety Equipment and Reclaimer
Dust Collector	Torrit Model #4DF-16, 6400 cfm
Recovery System	Ipec Model #VB-1200, Blast and Recovery System
Blast Generator	Clemco Model #SC-3676, 2000 Lb. capacity with Dead Man System
Blast Cabinet	Zero Model #BNP220-20, 40' x 50" x 42" (Working dimensions) Pressure Type 150 Lb. capacity, 900 cfm Dust Collector/Reclaimer
Blast Nozzle	Zero Model #SSR6, 1" Entry Venturi with Urethane Jacket and 1 1/4' threads
Portable Skid	Flame Spray, Inc. Model #5060

Dust Collection Equipment

During the spraying operation, aluminum dust (fine particulate) is generated due to the melting loss and over spray (edge loss) of the thermal spray devices. These dusts must be collected and disposed of through a collection device. There are two basic types of control devices; water wash and dry collection. The choice of using either of these systems is based on efficiency, portability and ease of disposal of the collected materials. Review local EPA requirements before selecting a control device to ensure conformity to local regulations.

Water Wash Spray Booths These types of systems are widely used for thermal spray shop applications. Due to their low efficiency for extremely fine particulate collection, they are not recommended for use with arc wire systems. (The arc wire systems produce particulate in a much finer form than the combustion wire or powder systems.) The basic function of a water wash booth is to convey airborne particulate from a given work area through a water curtain and through a series of baffles that collects the particulate into the water tank for subsequent removal as sludge. The air movement across the face of the booth is the basic design criteria for the volume of air required for the booth. The minimum velocity of air movement is 200 feet/minute of free air for TSA coating applications.

To determine the size of water wash booth required, calculate the cross sectional area of the work space where the spraying will be accomplished. (It pays to keep these dimensions to a minimum since the larger the work area, the more expensive the control device becomes.) Then, multiply by the air velocity.

Example:

Cross sectional area of work area
8′ wide x 8′ high =
64 sq. ft. x 200 ft./min. =
12,800 cfm (cu.ft./min.) required

Dry Collection Systems These systems are designed to work as a collection system for airborne particulate and are much more efficient in collecting all sizes of air borne particulate than water wash systems. The filters or bags can be cleaned and the dust is collected in 55 gallon drums. This makes the disposal very easy and clean. The design criteria is much the same as the water wash booths with a minimum of 200 feet/min. of free air required at the face

velocity for each square foot of cross sectional area of the work area. These systems are the only effective method of collection for arc wire spraying. The costs of the dry collection systems are approximately three times more expensive than water wash systems. For remote work (on-board or on-block) where dust collection from the spraying process is necessary, the dry collection systems are the most portable and afford the capability of collecting dusts from both the grit blast operation and the spraying operation.

EQUIPMENT TYPE	APPROXIMATE UNIT COST	OPERATION COST	MAINTENANCE COST
Water Wash	$ 12,000.00	$ 1.50/hr	$ 500.00/yr
Dry Collector	$ 28,000.00	$ 2.50/hr	$ 500.00/yr

Table 9-E Dust Collection Equipment Costs

Models Used for Cost Comparisons in Table 9-E:

EQUIPMENT TYPE	MANUFACTURER/MODEL
Water Wash	Binks, 8' Wide x 8' High, 12,000 cfm
Dry Collector	Torrit, 8' Wide x 8' High, 12,000 cfm

Safety Equipment

Air quality for the use of forced air breathing equipment is vital to the safety of personnel. Each system should produce breathing-quality air. A monitoring safety device should be installed in lines feeding the breathing apparatus to ensure the quality of air to the user. All air breathing equipment is to be NIOSH approved. The abrasive blasting and TSA coating operation generate noise levels in excess of 85 dBA. This level requires each person either operating the equipment or within the immediate area to wear protective hearing devices. Refer to the Safety section of this handbook for all other safety related equipments recommended for these processes.

EQUIPMENT TYPE	MANUFACTURER/MODEL	APPROX. COST
Blast Helmet	Bullard Model #32735	$ 420.00
Blast Helmet	Clemco Model #WSH	$ 400.00
Air Breathing Filter	Clemco Model #CPF20	$ 350.00
Airline CO Monitor Alarm	Clemco Model #CMA	$1,385.00
Spray Mask	Wilson Air Supplied Respirator Model 6000	$ 68.00

Table 9-F Safety Equipment Costs

Quality Assurance Equipment

The following equipments are required for the certification of operators and daily production QA verifications:

- Tensile Test Machine
- Thickness Gages (Magnetic or Electric)
- Bend Test Fixture
- Profile Test Kit
- Surface Pyrometers
- Temperature/Humidity Gauges

Note: An outside laboratory can be used for the tensile tests per ASTM 633.

EQUIPMENT TYPE	MANUFACTURER/MODEL	APPROX. COST
Tensile Test Machine	United #TM-20 (Lab Bench Type) KTA Tator #106-3 (Portable)	$18,000.00 $ 850.00
Thickness Gage	Zormco #5070-1020FM KTA Tator #F102 KTA Tator #EPP	$ 320.00 $ 850.00 $ 152.00
Bend Test Fixture	FSI Model #BTF20	$ 350.00
Profile Test Kit	Testex #CX Kit	$ 320.00
Surface Pyrometer	Service Tech #CPS	$ 267.00
Temp/Humidity Gage	KTA Tator #217	$ 825.00
Bend Test Sample	FSI Model #2-3 060	$ 0.75
Tensile Test Sample	FSI Model #1" OD	$ 22.00
Shape Test Sample	FSI Model #R-6 FSI Model #T-6	$ 6.50 $ 12.00

Table 9-G Quality Assurance Equipment Costs

Painting/Sealing Equipment

All existing shipyards are fully equipped to perform painting operations. Thermal spray sealing will use the same equipment as conventional production painting. Table 9-H lists the basic items required for thermal spray sealing.

EQUIPMENT TYPE	MANUFACTURER/MODEL	APPROX COST
2 Quart Pot	Devilbiss Model #KB424	$128.00
Spray Gun	Devilbiss Model #JGA502	$120.00
Hoses: Air Fluid	Western Hose Company (six foot lengths)	 $ 10.80 $ 15.36

Table 9-H Painting/Sealing Equipment Costs

Handling Equipment

Each facility will require forklifts, overheads, jib cranes or other handling equipment to transfer, store and stage components through each work station. Information and costs for this type of equipment can be obtained from local suppliers during facility design.

9.2 Thermal Spray Gun Selection

The choice of which thermal spray gun to use for aluminum application is a complex and controversial issue. Each manufacturer of thermal spray equipment maintains that they have the ultimate application device. This handbook will attempt to summarize the advantages and disadvantages of the three different types of thermal spray application equipment combustion wire, combustion powder and electric arc wire. In making this choice, here are a few suggestions

- Visit the equipment manufacturer's facility for an in-shop demonstration.
- Get a list of current customers who are using their equipment for similar applications; make phone calls and site visits to shipyards that have previously purchased and used their equipment.
- Determine what kind of technical support you can expect now and in the future.
- Determine the availability and costs of spare parts.
- Determine how long the manufacturer has been in the thermal spray business and if they are likely to continue to be able to support your future requirements.

Most manufacturers say that the cost to operate an electric arc system is less than a combustion system, i.e., gases, (fuel and oxygen) are more expensive than electricity. This is generally a true statement, however, the important factor is the cost of coating deposition. The cost of deposition can be significantly different than just the cost of energy to operate the systems.

The following are examples of the differences between systems

Deposit Efficiency

Both the combustion and electric arc systems have a vaporization factor (melting loss) for each pound of material fed through the system. The electric arc has an approximate deposit effiaency of between 50-70% (depending on the amperage) while the combustion wire and powder guns are at 90-95% for aluminum coatings. Deposit Efficiency (DE) is defined as the percentage of sprayed material that is actually deposited on the surface.

Gun Spray Rate capabilities

- Combustion Wire (1/8″): 10-12 lbs/hr
- Combustion Powder: 12-15 lbs/hr
- Arc Wire at 150 Amps: 10-12 lbs/hr
- Arc Wire at 250 Amps: 15-20 lbs/hr

When including the maximum deposit effiaency, the rates deposited areas follows:

Combustion Wire (1/8"):
9-11 lbs deposited/hr @ 95% DE
Combustion Powder
11-13 lbs deposited/hr @ 95% DE
Arc Wire; 14 gage, 150 Amps
7-9 Ibs deposited/hr @ 70% DE
Arc Wire; 14 gage, 250 Amps
11-14 pounds deposited/hr @ 70% DE

The combustion wire system can also use 3/16" diameter wire that will increase the pounds through the gun to 15-18 pounds/hour. The handling of this size wire is more difficult than 1/8" wire and the trade-off seems impractical for hand-held applications.

The arc wire systems can also use wire sizes of 11 gage and 1/8" although the amperage would need to be increased to melt these sizes. High amperage guns are primarily designed for high production work where higher spray rates are required. Higher amperages and larger diameter wires tend to create greater porosity within the coating that is undesirable for corrosion control applications.

Time And Material Calculations

To establish the amount of material and spray time to cover a given area, use the foIlowing formula

> Surface area (sq in) x coating thickness (in) x weight factor= pounds required to be deposited.
>
> Pounds deposited divided by DE = total pounds required.
>
> Weight factor for aluminum = 0.10 (pounds required per cu in of coating)
>
> Using the calculated total pounds required, divide by the spray rate per hour, which will equal the actual spray time.

Following are examples of the calculations necessary to determine the time and materials to apply a 10 mil coating of aluminum powder or wire to a 24" x 24" square plate. A flat plate two feet square will be used for the examples. Also an edge loss factor is required to determine true practical coverage. For combustion wire or powder a one inch border should be added for edge loss. For arc wire a two inch border should be added for edge loss.

Combustion Spray Example:

Known Factors:
- Spray rate, 12 lbs/hr
- 95% Deposit Efficiency
- Weight factor, 0.10 lbs/cu. in of coating
- Edge loss, 1" border
- Plate Size 24" by 24" x 1/4" thick (25''x25" is used to include the edge loss)

Step 1: Calculate surface area.
(Lx L = Area)

25" x 25" = 625 sq in (area)

Step 2: Calculate the volume (cubic inches) of coating required to cover the given area.

Multiply the area (sq in) by the coating thickness (inches). Use a coating thickness of 0.010 inches (10 roils) for low temperature (Type II) application calculations and 0.015 inches (15 roils) for high temperature applications (Type I).

625 sq in X 0.010 = 6.25 cu in

Step 3: Calculate the required weight (pounds) of deposited aluminum.

Multiply the cubic inches of coating by the weight factor for aluminum.

6.25 cu in x 0.10 wt factor= 0.62 lbs. deposited

Step 4 Calculate the total pounds of aluminum required with the factored deposit efficiency.

Divide the required pounds deposited by the deposit efficiency. (Convert the percentage to a decimal.)

0.62 lbs divided by 0.95 (95% DE)= 0.65 lbs required

To calculate the time required to spray any given amount of material, first determine the spray rate capacity in lbs. per hour (Use Appendix G: Tables and Charts, for gun capacity or refer to gun manufacturers data.) For this example, a twelve lbs. per hour spray rate has been selected.

Divide the spray rate per hour by 60 minutes to determine the spray rate per minute. Divide the total lbs. required by the spray rate per minute to determine time.

12 lbs/hr divided by 60 minutes = 0.20 lbs/min 0.65 Ibs. required divided by 0.20 lbs/min = 3.25 min

Summary To apply a combustion wire/powder coating 10 roils thick to a 24" x 24" date, 0.65 pounds of aluminum are required. Time required to spray is 3.25 minutes.

<u>Arc Wire Spray Exam</u>ple (14 gage wire at 150 amps)

Known Factors:
- Spray rate, 15 lbs/hr
- 70% Deposit Efficiency
- Weight factor, 0.10 lbs/cu. in. of coating
- Edge loss, 2" border
- Plate Sizs 24" by 24" x 1/4" thick (26" x 26" is used to include the edge loss)

Step 1: Calculate surface area (Lx L = Area)

26" X 26" = 676 sq in (area)

Step2: Calculate the volume (cubic inches) of coating required to cover the given area.

676 sq in X 0.010 = 6.76 cu in

Step 3: Calculate the required weight (pounds) of deposited aluminum.

6.76 cu in x 0.10 wt factor= 0.68 Ibs. deposited

Step 4 Calculate the total pounds of aluminum required with the factored deposit efficiency.

0.68 lbs divided by 0.70 (70% DE)= 0.97 lbs required

To calculate the time required to spray, first divide the spray rate per hour by 60 minutes to determine the spray rate per minute. Divide the total lbs. required by the spray rate per minute to determine time.

0.25 lbs/min = 3.89 min

Summa.qn To apply an arc wire coating 10 roils thick to a 24" x 24" plate, 0.97 pounds of aluminum are required. Time required to spray is 3.89 minutes.

From the previous examples, the reader can see that the arc wire process uses more aluminum and requires slightly more time to spray four square feet at 10 nils. This is primarily due to the lower deposit effiaency for the arc wire process.

Ease of Operation

Each type of thermal spray gun has handling characteristics that allow the operator various degrees of productivity.

The following paragraphs compare each type of gun.

The combustion powder gun has the most flexibility for hand held applications. It is light weight and has the capabilities to adapt angle heads and extensions to the gun. There are no wire feed mechanisms since the powder is delivered through a hose to the gun. This provides the operator with the greatest flexibility to maneuver and apply coatings.

When using a combustion powder system, gas bottle handling (oxygen / acetylene or propane and nitrogen) must be added to the operating costs. Moving, setting up and changing bottles is a time consuming procedure especially when working on-board or on-block where the bottles are positioned remotely from the actual work area. Jobs are accomplished all around the ship while the gas bottles are stored on the dock or pier.

The combustion wire gun also has very good flexibility, is light-weight and has angle head adapters with extensions. There are two major drawbacks in the wire system. The first is the wire feed that has to be constantly attended to, especially in tight areas. The second is the high maintenance required due to the dust or dirt collected during spraying. There are many moving, close-tolerance components within the gun that can be detrimentally affected by the operating conditions. When using a combustion wire gun, gas bottle handling is the same as the combustion powder system with the exception of nitrogen, which is not required for wire spraying.

The electric arc systems have slightly heavier guns than the combustion system. Currently, extensions or angle heads are not available for full production. (There may be some manufacturers who are working on development of angle heads and extensions). Wire feed problems exist when long leads are used. (35'-50'). The arc systems produce an ultra violet light when operating. This makes it necessary for operators to wear shaded lenses that can limit their visibility in some areas. When using the arc system, there is no way to preheat the surface with the gun, so other heat sources are required. Due to the melting Ioss there is substantiality (2-3 times) more particulate latent smoke generated than with the combustion systems. As a plus, the arc wire system needs only electricity and air to operate, so gas bottle handling is not an issue.

Difficulty Factors

Each job will have its own unique difficulty factors primarily determined by component geometry. It is important to include these factors when determining the time and materials necessary to apply a TSA coating. Difficulty factors can reduce the optimum production rate substantially.

Easily accessible flat surfaces are considered high efficiency applications, with factors up to 80% of the optimum production capabilities. For components having more complex geometries, such as angles or shapes, limited access can lead to difficulty factors as low as 10-20% of the optimum production capabilities. Normally areas on-block or on-board are more difficult to process than those same components would be in a shop environment. Use difficulty factor percentages from 10-80% of optimum production capabilities to adjust the time and materials for each coating job. Experience will determine the most realistic factors to use.

Summary of Comparisons of Arc Wire vs. Combustion Systems

The preceding paragraphs have described the benefits and limitations of the systems. ***There*** may be times when having the option to use any one of the three systems for a particular job would be advantageous. As a facility grows, the acquisition of all three types of equipments makes the most sense.

The dilemma is choosing the system to start with.

The combustion type systems are recommended for a facility who is just starting out. Their flexibility for all types of applications has the greatest initial benefits. The combustion systems are more beneficial for small parts and tight areas where access is difficult, however, the arc system would be more practical for large, flat, open areas.

Purchase costs for various thermal spray gun systems are summarized in Appendix A, Table A-5. System costs and capabilities are listed for several manufacturers and suppliers.

9.3 Operational Costs Analysis

This section outlines the operational costs associated with the performance of the thermal sprayed aluminum (TSA) process.

Costs to operate the various gun types are presented and summarized in Table 9-N. Later in the section, sample production costs and rates are presented for the complete TSA process.

The spray application costs discussed below are considered theoretical since they are based on coverages calculated by formula using gun manufacturer's data. These are spray costs only and do not include set-up, handling, masking, blasting and difficulty factors or edge losses. Also, the costs are based on applying exactly ten roils. Any additional coating thickness increases the costs and spray rates proportionally.

Fuel consumption rates are based on manufacturers published information and fuel costs are 1991, San Diego pricing. The cost of air is based on energy and maintenance rates for compressors.

COMBUSTION WIRE GUN - ACETYLENE

GASES	GUN FUEL CONSUMPTION (CU.FT/HR.)*	FUEL COST PER 100 CU FT**	FUEL COST PER HOUR
Oxygen	90	$ 1.05	$0.94
Acetylene	40	$10.00	$4.00
Air'"	--	. -	$0.32
		TOTAL	$5.26

l Per Gun Mfg (Metco) ** Per Local Gas Supplier
l " Cost to Operate Compressor

Table 9-1 Combustion Wire Gun Fuel Costs (Using Acetylene as Fuel Gas)

The following operational costs are based on a theoretical coverage of 79 sq ft' using a combustion wire gun (oxygen and acetylene) at 12 pounds per hour with a 95% Deposit Efficiency (DE), coating

Labor:	1 hour @ $40.00/hour =	$40.00
Material:	1/8" Alum @ 2.30/lb^2 x 12 lb/hr =	$27.60
Gases:	Oxygen, Acetylene and Air =	$ 5.26
	Total Cost	$72.86

Theoretical cost/sq ft = $7286 divided by 79 sq ft = $0.92sq ft

1 To determine the theoretical coverage (sq. footage) per hour, use this formula:

lbs/hr. sprayed x DE = lbs. required
lbs. required divided by 0.10 (wt factor for aluminum) = cu in
cu. in. divided by coating thickness = sq. in.
sq. in. divided by 144 (sq. in/sq. ft) = sq. footage

2 The powder cost is based on Metco's 1992 price for 500 lbs.

COMUBSTION WIRE GUN - PROPANE

GASES	GUN FUEL CONSUMPTION (CU.FT/HR.)*	FUEL COST PER 100 CU FT**	FUEL COST PER HOUR
Oxygen	161	$ 1.05	$1.69
Propane	30	$ 3.05	$0.91
Air***	--	---	$0.32
		TOTAL	$2.92

* Per Gun Mfg (Metco) ** Per Local Gas Supplier
*** Cost to Operate Compressor (40 cfm @ 80 psi)

Table 9-J Combustion Wire Gun Fuel Costs (Using Propane as Fuel Gas)

The following operational costs are based on a theoretical coverage of 79 sq. ft. using a combustion wire gun (oxygen and propane) at 12 pounds per hour with a 95% DE, coating thickness 10 mils.

Labor:	1 hour @ $40.00/hour =	$40.00
Material:	1/8" Alum @ 2.30/lb[1] x 12 lb/hr =	$27.60
Gases:	Oxygen, Propane and Air =	$ 2.92
	Total Cost	$70.52

Theoretical cost/sq ft = $70.52 divided by 79 sq ft = $**0.89/sq ft**

COMBUSTION POWDER GUN

GASES	GUN FUEL CONSUMPTION (CU.FT/HR.)*	FUEL COST PER 100 CU FT**	FUEL COST PER HOUR
Oxygen	95	$ 1.05	$0.99
Acetylene	60	$10.00	$6.00
Nitrogen	5	$ 1.05	$0.05
Air***	--	---	$0.32
		TOTAL	$7.36

* Per Gun Mfg (Metco) ** Per Local Gas Supplier
*** Cost to Operate Compressor (40 cfm @ 80 psi)

Table 9-K Combustion Powder Fuel Costs (using Acetylene as Fuel Gas)

The following operational costs are based on a theoretical coverage of 98 sq ft using a combustion powder gun (oxygen and acetylene) at 15 pounds per hour with a 95% DE, coating thickness 10 mils.

Labor:	1 hour @ $40.00/hour =	$40.00
Material:	Alum Powder @ 8.00[2] x 15 lb/hr =	$120.00
Gases:	Oxygen/Acetylene/Nitrogen/Air=	$ 7.36
	Total Cost	$167.36

Theoretical cost/sq ft= $167.36 divided by 98 sq ft = $**1.71/sq ft**

[1]The cost for aluminum wire is based on Miller Thermal's 1992 price for 500 lbs.
[2]The powder cost is based on Metco's 1992 price for 500 lbs.

ARC WIRE GUN

GUN ELECT. CONSUMPTION AMPS/HR	KW/HR*	ELECTRICITY COST (KW-HR)**	ELECTRICAL COST PER HOUR	AIR COST PER HOUR	TOTAL COST PER HOUR
150	6.5	$0.10	$0.65	$0.32	$0.97
250	9.5	$0.10	$0.95	$0.32	$1.27

l This value represents the electrical service required per hr   l 'Local energy costs /Kw-Hr

Table 9-L Arc Wire Gun Fuel Costs (150 and 250 AMPS)

The following operational costs are based on a theoretical coverage of 97 sq ft using a arc wire gun at 250 amps, and 58 sq ft at 150 amps at 20 and 12 pounds respectively per hour with a 70% DE, coating thickness 10 roils. The deposit efficiencies and amperages (Ibs/hr) may vary depending on the manufacturer's equipment. The values stated below represent a Metco 4RG Arc Wire System.

The TSA cost for a 250 Amp Arc Wire Gun is as follows:

Labor:	1 hour @ $40.00/hour =		$40.00
Material:	Alum Wire 14 ga @ 3.00[1] x 20 lb/hr =		$60.00
	Electricity/Air =		$ 1.27
		Total Cost	$101.27

Theoretical cost/sq ft = $101.27 divided by 97 sq. ft. = $1.04/sq ft

The TSA cost for 150 Amp Arc Wire Gun is as follows

Labor:	1 hour @ $40.00/hour =		$40.00
Material:	Alum Wire 14 ga @ 3.00 x 12 lb/hr =		$36.00
	Electricity/Air =		$ 0.97
		Total Cost	$76.97

Theoretical cost/sq. ft. = $76.97 divided by 58 sq. ft. = $1.33/sq ft

Maintenance

Of the three systems the electric arc gun is the least expensive in time and replacement parts to maintain. The combustion powder gun is a close second and the combustion wire system is the most expensive. The following table represents approximate maintenance hours and spare part costs per month based on operating the systems 4 hours per 8 hour, 5 day shifts. This is a general comparison chart; specific times and spare part costs will depend on the equipment and usage.

[1]Wire cost is based on Tafa's 1992 price for 500 lbs.

GUN TYPE	GENERAL CLEANING	SPARE PART REPLACEMENT	PART COSTS	TOTAL COST/ 80 HRS*
Arc Wire	5 Hrs	½ Hr	$ 20.00	$ 240.00
Combustion Powder	5 Hrs	4 Hrs	$ 75.00	$ 435.00
Combustion Wire	7 Hrs	4 Hrs	$ 75.00	$515.00

*The assumed labor rate is $40.00/hour

Table 9-M 80 Hour Maintenance Costs

Table 9-N summarizes the system cost comparisons presented in the previous pages. Results show the combustion wire gun using propane fuel to be the least expensive to operate and the combustion powder/acetylene gun to be the most expensive by $0.78 per square foot. For small jobs, this difference in operating cost would not be significant. For example, a 100 square foot area would cost $78.00 more to spray using the powder gun.

The costs shown here are intended for comparison of gun systems only and do not reflect any additional costs associated with other tasks required to accomplish the intended job. This data is not recommended for job cost estimating. More complete production cost data is presented in the following sections.

GUN TYPE	SQ FT COVERAGE PER HOUR	COST PER SQ FT				
		Labor	Material	Fuel	Maint.	Total
Combustion Wire-Acetylene	79	$.51	$ .35	$.07	$.08	$1.01
Combustion Wire-Propane	79	$.51	$ .35	$.04	$.08	$.98
Combustion Powder-Acetylene	98	$.41	$1.22	$.08	$.05	$1.76
Arc Wire 150 Amps	58	$.69	$ .62	$.02	$.05	$1.38
Arc Wire 250 Amps	97	$.41	$ .62	$.02	$.03	$1.08

Table 9-N Gun Operational Costs Summary (Aluminum Coating Thickness = 10 Mils)

Production Costs

Tables 9-O and 9-P provide examples of time and material cost analyses for typical applications in-shop and on-board or on-block, performed by a certified, experienced TSA facility. These examples demonstrate the cost differences for shop and on-board applications for two different components of approximately the same area. Difficulty factors are also reflected in these examples. They include direct labor only, without supervision. At the bottom of each table, costs per square foot are calculated assuming a $40.00 per hour labor rate. These figures are provided to illustrate the higher costs to perform work on-board, and should not be used for job cost estimating.

PROCESSING STEPS	TIME (MIN.)	MATERIAL	MATERIAL COST
Receiving (log in)	5		
Mask non ferrous areas	10	Tape	$ 1.10
Handling to blast station	10		
Blast with straight nozzle	60		
Blast with angle nozzle	30		
Inspection	5		
Blast/Pick up missed areas	5	Grit/Air	$ 3.92
Remask damaged masking	5	(11 lbs-recycled)	
Inspection	5	Profile Tape	$ 1.00
Prepare/TSA coat/Inspect test sample and record results	10	Gases	$ 2.47
Record temp/humidity	5	Air	$ 0.16
TSA coat/angle head	15	Wire (6 lb)	$13.80
TSA coat/straight head	45		
Inspect TSA coating	5		
Pick up any low areas TSA	5		
Inspect	5		
Handle to Paint Area	5		
Seal with diluted 150	15	F 150 - (1 qt.)	$ 6.25
Demask	5		
Final Inspection	5		
Packaging	5		

Note: One man is used for all operations.

Total Labor: 4.25 Man hours @ $40.00 = $170.00
Materials = $ 28.70
Total Cost: $198.70 divided by 35 sq ft = **$5.68/sq ft**

Table 9-O In Shop TSA Application For A New Water Tight Door (approximately 35 sq ft)

PROCESSING STEPS	TIME	MATERIAL	MATERIAL COST
Prepare equipment	2 men 30 min		
Set-up on-board	2 men 30 min		
Install temporary enclosures	1 man 25 min		
Mask	1 man 25 min	Tape	$48.00
Blast/straight nozzle	1 man 45 min	Grit (100 lbs)	$36.00
Blast/angle nozzle	1 man 30 min	Air	$4.75
Inspect	1 man 5 min		
Blast/pick up missed areas	1 man 5 min		
Inspect/Record anchor tooth	1 man 5 min	Profile Tape	$1.00
Vacuum grit	2 men 20 min		
Prepare/TSA coathspect test sample and record results	1 man 10 min	Gases	$2.47
Record temp/humidity	1 man 5 min	Air	$0.64
TSA coat/angle head	1 man 30 min	Wire (6 lbs)	$13.80
TSA coaffstraight nozzle	1 man 45 min		
Inspect	1 man 5 min		
Pick up any low areas TSA	1 man 10 min		
Inspect	1 man 5 min		
Seal with diluted 150	1 man 20 min	F 150(1 qt)	$6.25
Demask	1 man 10 min		
Final Inspection	1 man 10 min		
Remove enclosures	1 man 20 min		
Remove equipment	2 men 30 min		

Total Time: 8.8 Man Hours @ $40.00= $353.00
Materials: =$114.64
Total Cost: $467.64 divided by 35 sq ft = 13.36/sq ft

Table 9-P On-Board Ship or On-Block Application - Foundation and 6“ Around Deck (Approximately 35 Square Feet)

Time Studies

Table 9-Q summarizes the results of a sample time study of on-board thermal spray work at NASSCO shipyard. The study was conducted over several months during mid-1991. The deck areas surrounding several foundations of various sizes were prepared, coated and sealed. The foundations had been previously sprayed in the shop. This table shows the time distribution (in percent) of the primary operations. Results indicate that delay, waiting and personal time, and equipment set-up consume over thirty percent of the total job time. The table also gives average production rates (in square feet per hour) for the primary operations and the overall job. It should be noted that these rates are applicable to this job type only and may not include all sub-operations or processing steps.

OPERATION	TOTAL TIME* (Hours)	% OF TOTAL	AVERAGE TIME PER FNDN (Mins)	AVG RATE (Ft^2/Hr)
Set Up Equipment	5.7	14.2	19.0	---
Anchor Tooth Blast	7.9	19.7	26.3	84.2
Clean/Remove Grit	7.1	17.7	23.7	93.7
Apply Thermal Spray Aluminum	8.5	21.1	28.3	78.2
Seal Coat (F-150)	2.0	5.0	6.7	332.5
Remove Equipment	2.3	5.7	7.7	. —
Subtotal	33.5	83.3	1.9 Hrs	19.9
Delay/Waiting Time	4.0	10.0	13.3	.—
Instruction/Personal Time	2.7	6.7	9.0	. —
Total	40.2	100.0	2.2 Hrs	16,5

***Represents 18 Foundations of Various Sizes; Total Area = 665 Ft.**

Table 9-Q Time Study Results for NASSCO On-Board TSA Work

Table 9-R represents the partial results of an industrial engineering time study of TSA applications performed at the SIMA, San Diego, Corrosion Control Shop in 1985 (Ref. 4). The times shown are standard man-hours for TSA coating and final painting of various components, and an allowance factor of 2.6 is applied to adjust for personal time, transportation between stations and equipment set-up. Preparation, masking, abrasive blasting, thermal spraying and seal coating represent about seventy percent of the listed times. This table is provided primarily to compare the times of the various components listed. This data, together with the time and rate information presented earlier in this section, may be useful as a guide to projecting actual production times for particular TSA coating applications.

COMPONENTS	STD. TIME (HRS)	COMPONENTS	STD. TIME (HRS)
Bar, Chain	3.6	Hatch, Large	16.4
Bolt, Baxter	1.3	Hinge	2.0
Bolt, J-Bar	1.7	Ladder, Vertical	4.4
Brace, Accom-Ladder	3.2	Locker, Pyro	10.1
Bracket, Bottle Rack	1.5	Manifold, Elbow	4.3
Bracket, Light	1.7	Mount, Big Eyes	2.6
Bracket, Helo Net	0.7	Mount, Saluting Gun	2.4
Bracket, Scupper	1.8	Fitting, Nato	3.2
Bracket, Sliding	1.8	Box, P-250	8.4
Padeye	3.3	Base, P-250 Box	7.8
Controller, Capstan	2.6	Plate, Fuel Gauge	0.7
Cleat, Portable	1.4	Rack, Bottle Gas	7.6
Counterweight,	6.8	Roller, Ramp	3.1
Director	2.1	Reel, Line	7.9
Director,	3.6	Mount, Reel Line	2.8
Counterweight	4.8	Screen, Bullnose	3.9
Coupling Pipe	2.9	Scuttle	5.6
Cover, 1 MC	1.6	Shackle, Unrep	5.9
Cover, Chain Locker	5.6	Sign, Parking	2.0
Cover, Chock	1.6	Blower, Soot	3.4
Cover, Edge Light	1.0	Sheave, Fairlead	4.4
Cover, Hawse Pipe	3.2	Stanchion	2.5
Cover, Junction Box	6.6	Support, Stanchion	3.0
Cover, VDS 3-Dog	4.1	Roller, Stopper	1.6
Cradle, Lift Raft	8.7	Strongback	4.0
Davit, Portable	1.5	Support, MWB	5.0
Socket, Portable Davit	4.5	Tripod, 50 Cal	3.8
Door, Watertight	1.7	Shield, 50 Cal	5.0
Eye, Boat Lifting	3.4	Carriage, 50 Cal	2.4
Mount, Fas Bulkhead	2.2	Yoke, 50 Cal	2.7
Swivel, Fas	4.8	Yoke Mount, 50 Cal	1.6
Piping, Fas	4.0	Valve, 1/2"	3.7
Arm, Fas Swivel	3.5	Valve, Globe, 1"	3.1
Assembly, Fas Swivel	3.6	Valve, Globe, 2"	2.9
Frame, Net	1.4	Valve, Regulating, 3"	2.6
Frame, Stanchion	3.3	Valve, Relief, Exhaust	3.9
Guard, Winch Safety	1.6	Vent, Fuel Oil	1.5
Handle, Strainer	8.6	Wrench, Anchor	3.8
Handrail, Debark	1.6	Wrench, Propeller	1.0
Handwheel, (4")	5.7	Yoke, Searchlight	2.2

Table 9-R SIMA Time Study Results

9.4 Consumables

Table 9-S Provides a sample list of consumable items that would be required to operate and maintain a full-service thermal spray facility utilizing various gun types. The unit costs shown represent 1991 prices as quoted by San Diego suppliers. The average cost per month data is included to provide a basis for developing budgetary estimates of material expense for an ongoing facility.

These monthly costs were based on coating approximately 1500 square feet of various components and ship areas at NASSCO using a combustion wire system. Consumable costs will vary depending on the work type and location (shop vs. ship). It should be noted that the most significant consumable cost is for aluminum oxide grit used for anchor-tooth blasting. This points out the need for efficient use, containment and recycling of this expensive grit. (NOTE: Appendix B contains a comprehensive list of consumable suppliers.)

ITEM	UNIT COST	AVERAGE COST/MO*
Ear Plugs	$10.16/200 pr	$5.08
Cotton Gloves	$0.47/pr	$157.92
Rubber Gloves, Painting	$1.14/pr	$9.12
Rubber Gloves, Blasting	$18.81/pr	$37.62
Silver Duct Tape	$3.50/roll	$35.00
Silicon Tape	$27.43/roll	$237.73
Silicon Rubber Plugs	sm $20.00/100	$5.00
	med $25.00/100	$5.00
	irg $30.00/100	$6.00
Silicon Sheeting	$88.801yard	—
Press-o-film	$29.00/roll	$9.67
Cotton Rags	$26.09/bundle	$4.35
Gun Parts, Various	varies	$100.00
Blast Nozzles	$60.00 Each	$60.00
Oxygen	$0.02/CU. ft.	$71.03
Acetylene	$o.10/cu. ft.	$326.00
Propane	$o.03/cu. ft.	--
Steel Shot	$0.32/Ib.	--
Alum Oxide, 24 Grii	$0.36/Ib.	$1237.00
Flame Spray Wire, 1/8″	$2.30/Ib.	$482.17
Arc Spray Wire, 14 Ga.	$3.00/Ib.	
Aluminum Powder	$4,60/Ib.	
Formula 150 (Epoxy) (seal coat only)	$11.75/gal.	$587.50

*Represents approximately 1500 sq. ft. of spray area

Table 9-S Consumable Costs

10. IMPLEMENTATION OF A SHIPYARD PROGRAM

10. IMPLEMENTATION OF A SHIPYARD THERMAL SPRAY PROGRAM

This section is intended to offer guidance to a shipyard faced with a new contract requirement to provide corrosion control in the form of thermal sprayed aluminum as part of a new building program or ship repair/conversion contract. However, shipyards with currently established corrosion control (CC) or thermal spray aluminum (TSA) programs may also glean useful information from this section.

Information and recommendations provided herein are drawn primarily from NASSCO's experience with setting up a ground-up TSA program to support the US Navy's AOE new building program. This effort took place over an approximately two year interval from mid 1987 to early 1989. NASSCO's approach included the appointment of a Corrosion Control Engineer assigned to the Production Outfitting (Coatings) Department to coordinate and supervise the TSA program implementation. NASSCO also chose to work closely with an experienced local consultant/supplier - Flame Spray, Inc.

Almost every major shipyard in the U.S. has been required to provide TSA coatings on U.S. Navy contracts over the past decade. Undoubtedly, there have been various acceptable approaches taken to meet this requirement – each with a unique list of pros and cons and lessons-learned. NASSCO's approach should be kept in context and viewed as one possibility among many. It should also be mentioned that NASSCO's model, the AOE procurement, is a large and complex program with a significant requirement for TSA coatings. For a contract of smaller scope, a correspondingly reduced perspective would apply to the implementation elements presented in this section.

The implementation flow chart presented in Fig. 10.1 summarizes the key elements and relationships needed to implement a comprehensive shipyard TSA program. These elements are then discussed in detail in the remainder of this section.

10.1 Estimating and Budgeting

The estimating activities to support a thermal spray program usually begin in the bid stage prior to contract award. Estimators, or cost engineers, are tasked with reviewing the contract proposal and specifications provided by a prospective customer. An estimate is then developed for the thermal spray or corrosion control (CC) portion of the contract to include all labor and material costs. Therefore, to ensure an accurate estimate, the estimators need at least a basic understanding of thermal spray processes.

Estimators again enter the picture following contract award. The original bid estimate is reviewed and, if necessary, further refined to accurately reflect the total scope of work required to support the thermal spray effort. This additional estimating activity is primarily intended to provide visibility of the overall thermal spray work content to Engineering, Production and shipyard management.

Also, the Estimating, or Cost Engineering, Department usually takes the lead in conducting "make-or-buy" analyses related to the thermal spray program. The purpose of these analyses is to determine whether it is more cost effective to set up an in-house thermal spray facility or to subcontract the aluminum coating work to a qualified outside vendor. There are many elements to this decision process, and following is an outline of the steps undertaken by NASSCO.

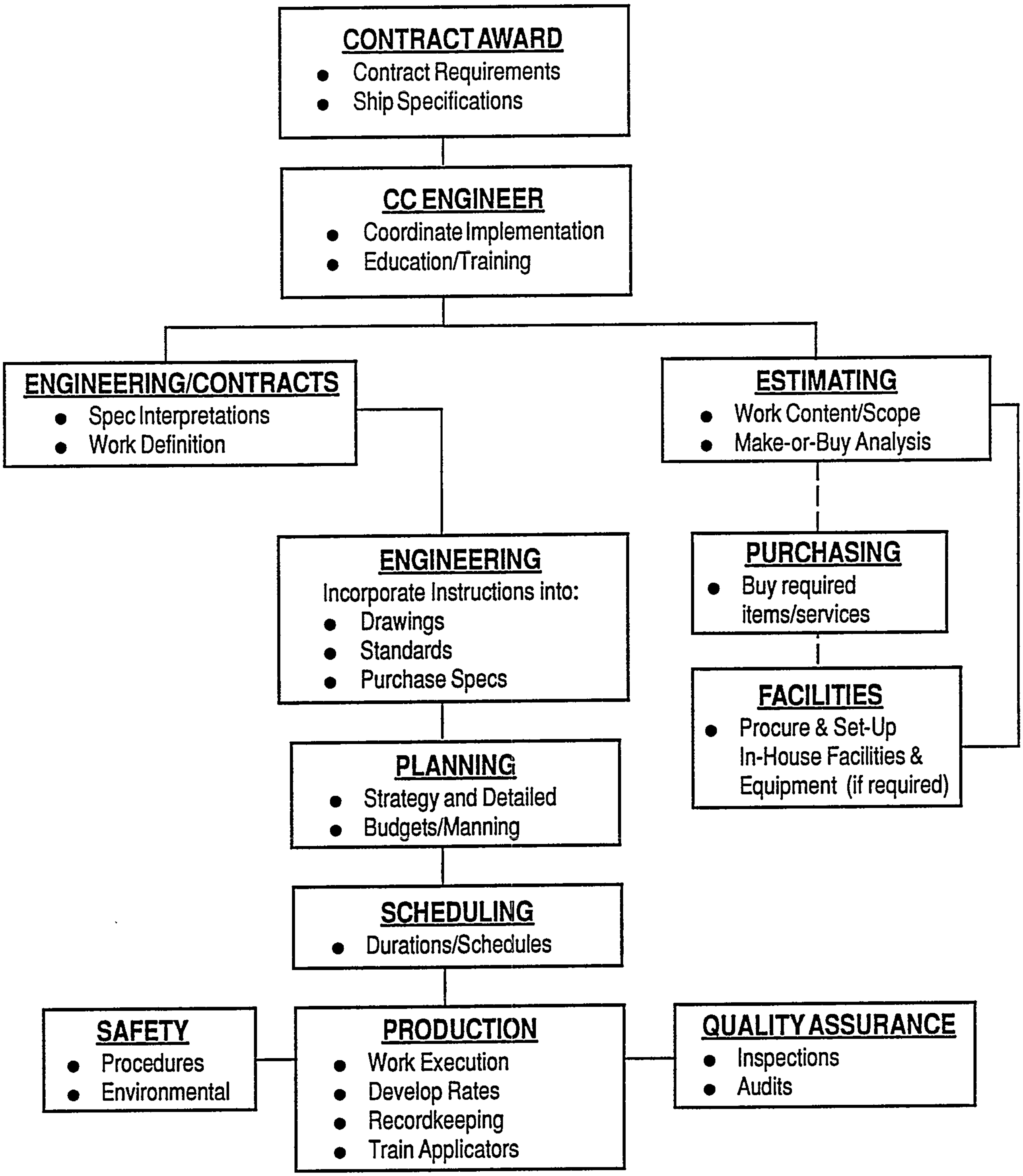


Fig. 10.1 Thermal Spray Program Implementation Flow Chart

- Based on initial bid estimates and specification requirements, determine the scope of thermal spray work (total square footage) to the best possible degree of accuracy.

- Analyze list of items to determine if any work is too complex or for other reasons could not be efficiently done in-house. (Example Items requiring disassembly which would void vendor warranties.)

- Determine total work scope and approximate time duration for proposed in-house thermal spray applications.

- Determine in-house labor requirements and training cost to provide support for the thermal spray effort. (See Section 10.3: Planning, scheduling, Manning). Also, at this point an estimate will be needed of labor rates for newly trained workers to perform thermal spray activities — with a learning curve factored in.

- Analyze shipyard facility arrangement to determine if adequate space is available to set up a thermal spray facility in an appropriate location (Recommended adjacent to the central small parts painting facility).

- Obtain vendor information regarding cost of purchasing or leasing the appropriate thermal spray facilities and equipment based on required scope of work

- Issue Requests for Quote to thermal spray subcontractors to obtain cost estimates for having work done outside, or to have a subcontractor set up shop inside the shipyard.

- Compare cost to perform thermal spray coating operations in-house versus turning over all or part of the coating work to a qualified subcontractor.

- Based on the cost comparison, a management decision can be made regarding set-up and execution of the thermal spray program. Usually, the start-up facility and equipment costs can be spread over several contracts, and the facility is considered a capital investment.

There are other, somewhat intangible factors that should be considered in the make-or-buy decision. These include

- Could an in-house facility be used to support additional work, such as ship repair/overhauI contracts or outside commercial work brought in through sales or marketing efforts?

- Performing work in-house would probably allow better control and flexibility in planning and scheduling thermal spray application.

- If work is subcontracted, delays or interferences caused by the shipyard may result in increased costs due to subcontractor claims.

If the decision is made to set up an in-house thermal spray facility, the information in this handbook provides valuable guidance.

The initial allocation of budgets for thermal spray activities is a natural follow-up to the estimating process. The same information needed to prepare a comprehensive estimate can be used to establish preliminary man-hour and material budgets. These initial budgets can later be refined by the involved production departments once actual cost return and rate data is collected. (See Section 10.3: Planning, Scheduling and Manning.)

10.2 Engineering

As seen in the flow chart (Fig. 10.1), Engineering support to the thermal spray program should begin immediately following contract award. One of the first decisions to be made is how to organize and staff the program. If a Corrosion Control Engineer is appointed, he or she will coordinate the thermal spray program implementation. The Corrosion Control Engineer can be assigned to the Engineering Department or to the appropriate Production Department, however, it is important he or she has the necessary technical and administrative background, and Ievel of authority to ensure a successful program execution. This position should be viewed primarily as a technical project manager. If a Corrosion Control Engineer is not used, the required technical expertise and coordination will need to come from the appropriate engineering disapline.

The primary engineering effort related to the thermal spray program centers around interpretation of specification requirements Ieading to a clear definition of work content. The level of this effort will depend on the quality and complexity of the contract specification pertaining to corrosion control in general and TSA specifically. Given a simple, relatively easy to interpret specification, the engineer's job becomes straight-forward. The alternative however, can be a drawn-out, complicated dialogue with the customer, probably involving the Contracts Departments to resolve interpretation conflicts. If and when this scenario occurs, it pays to bring all issues to light as early as possible and quickly work to agreeable resolutions.

Another engineering responsibility is to provide clear, definitive direction to the Coatings Department regarding the location, extent and method of application for all items required to receive a TSA coating. This can be accomplished in several ways. First, a corrosion control or thermal spray guidance document (called a "schedule") is produced. This document contains a list of all TSA items required by specification, as interpreted by Engineering. The schedule indicates item location on-board ship and any special notes or instructions to assist the Coatings Department in proper application. Engineering may decide to create a drawing or plan in addition to, or in place of, the Corrosion Control Schedule. The drawing would contain essentially the same information, however a drawing format might be more practical or useabIe for production.

Since these engineering documents are intended to assist production with coating application, they are best produced up-front prior to the start of production work. There is however, a unique problem that arises in the case of a first-of-a-class ship procurement. Ship design is usually not completed early enough to support up-front development of a detailed corrosion control drawing or schedule. In this case, the Corrosion Control Schedule or drawing would need to be developed during ongoing ship design, and exact locations and quantities would be provided as they become available.

To further ensure that thermal spray instructions are properly conveyed to both Production and Materials (Procurement) Departments, thermal spray information and procedures can be incorporated into engineering design drawings, purchase specifications and standards. To this end, NASSCO developed a code system (Fig. 10.2) for identifying special coatings and included these codes on the appropriate drawing bills-of-material. This system permits the special information to be readily conveyed to production supervision, planners, buyers and subcontracts administrators. In addition, both general

SYSTEM	CODE
Wire Sprayed Alum. - High Temp	1F
Wire Sprayed Alum. - Low Temp (Bilges, Wetspaces)	2B
Wire Sprayed Alum - Low Temp (Exterior Topside)	2X

Fig. 10.2 Thermal Spray Identification Codes

and specific notes were placed on drawings as necessary to provide further information and clarification. Fig. 10.3 summarizes the engineering corrosion control identification process.

The engineering activities discussed in this section form the foundation of a shipyard thermal spray program. The importance of these efforts should not be underestimated since they are critical to successful program implementation.

10.3 Planning, Scheduling and Manning

Comprehensive, up-front planning can be the key to a successful shipyard thermal spray program. A good planning effort will set the stage for a smooth transition between the various elements of the program and will help avoid potential problems and pitfalls downstream. The best way to begin planning is to first become saturated with information and knowledge in the area of thermal spraying. In addition to this handbook, various resources and references are available to obtain information regarding thermal spraying. These are included in Section 12, References.

Planning for a thermal spray program can and should begin relatively early in the sequence of events. Preliminary or advanced strategy planning can take place together with the up-front Engineering and Contracts efforts to interpret specifications and clarify work content. Planning at this stage would consist primarily of the following elements:

- Determination of the most cost effective stage of construction (In-shop, In-field, On-block or On-board) for TSA application.
- Development of identification and tracking procedures for fabricated or purchased items to be aluminum coated and which will move through various work stations in the shipyard prior to installation.
- Determination of the most cost-effective stage of construction for installation of parts or items requiring TSA application.
- Development of a special coding system to be included on engineering drawings and other production instruction documents. This code would provide instructions for the proper coating and installation sequence of TSA items.

Ideally, the preliminary planning effort would be coordinated by the Corrosion Control Engineer with support from Engineering and Production planners.

When all required thermal spray work has been defined by Engineering and actual work content and scope has been determined by Estimating, a more detailed planning phase can begin. Detailed planning would cover the following areas

- Re-examination and refinement of planning elements previously examined during preliminary planning.
- Analysis of projected labor rates required to accomplish TSA application and related activities.

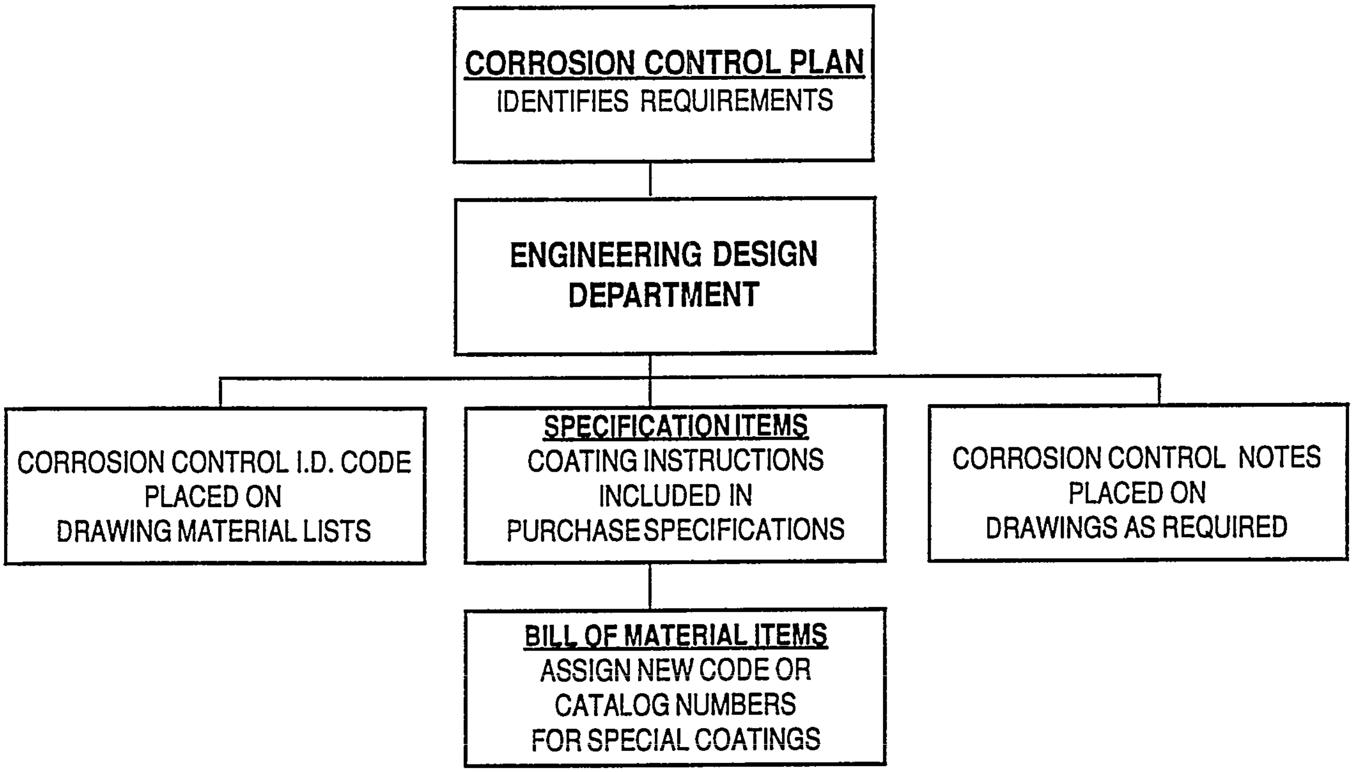


Fig. 10.3 Engineering Corrosion Control Identification Process

- Calculation of all potential time and material costs associated with the TSA processes in order to establish and assign budgets to the involved production areas.

- Determination of manpower requirements to support TSA across all construction stages.

Detailed planning is most effective when performed for each construction stage. For example, all thermal spray work to be accomplished in the shop would be analyzed and separated into discrete work packages to allow accurate scheduling and manning. This same approach would be followed for work intended for the assembly, on-block,and on-board stages. Detailed planning would be performed primarily by production planners in the lead trade department for TSA — usually the Paint Department.

Scheduling of thermal spray work activities begins immediately following detailed planning. This process consists of first assigning realistic time frames or windows to the various activities required to complete a thermal spray work package. The next, and probably most critical, step in scheduling is the creation of an integrated schedule for work packages in each construction stage. For maximum visibility these schedules-by-stage would cover three basic time periods:

- short range — work to be accomplished in a four to six week period

- mid range — work to be done in the upcoming 8 to 12 weeks

- long range — work scheduled for the next four to six months and beyond.

For tasks of long duration — a year or more — an overall, start-to-finish schedule may be desirable up front. This type of schedule, however, would undoubtedly require frequent revising and fine tuning.

Many scheduling formats exist and one of the most common and useful is the Gantt chart, which uses a horizontal bar time line to depict events occurring by day, week, month or year. The point here is to pick a workable format and stick with it.

The importance of accurate planning and scheduling to a thermal spray program cannot be overstated. Planning is an on-going, dynamic process that requires frequent input and revision by dedicated personnel.

Staffing Requirements

A thermal spray facility requires the following minimum staffing:

- Supervisor/Lead Foreman
- Maskers
- Abrasive Blasters
- TSA Operators
- Painters
- Q.A. Inspector (not full-time)
- Maintenance Personnel (not full-time)
- Forklift/Crane Operator (not full-time)
- Electrician (not full-time; required for hooking up services on-board or on-block)

A thermal spray operator can often be trained to perform several of the required tasks, such as masking, blasting, aluminum coating and sealing. This results in a more efficient use of manpower, however, a particular shipyard's labor agreements may prohibit such cross training.

A key question regarding manning arises and should be addressed early in program implementation. That is, which trade will be trained to apply the TSA coatings — painters or welders? An argument can be made for either of these trades as applicators.

The TSA coating process utilizes an oxygen-acetylene combustion or electric arc spray gun that can be viewed as being similar to the welding process. Primarily for this reason, welders can become qualified TSA applicators. However, since thermal spraying is a coating process, painters can easily learn to use the equipment.

Another important consideration in this decision is the surface preparation required by blasters prior to TSA coating. Painters and blasters normally reside in the same department and thus their work can be easily coordinated. In some cases, painters can be trained to perform both surface preparation and coating. If welding is the lead trade for TSA coating, surface preparation would need to be scheduled through the Paint/Blast Department, possibly resulting in delays.

A final factor in trade selection for thermal spraying is union representation. In shipyards where labor unions are present, previously negotiated labor agreements may dictate which trade will perform TSA coating application. In any case, the appropriate unions may need to be involved in the decision process.

NASSCO, like most shipyards, has chosen to use painters for TSA coatings. Therefore, the information in this handbook is presented from the painter-as-applicator perspective.

10.4 Organizational Interface

As can be seen from the implementation flow chart (Fig. 10.1) and information presented in this section, a shipyard thermal spray program is dependent upon relationships between various departments and organizations within (and sometimes outside) the yard. These interrelationships are further illustrated in Fig. 10.4. An example of organizational interaction can be seen in the integration of information from Engineering to Production Planning during NASSCO's thermal spray program. First, planning requested assistance from the In-formation Systems Department to retrieve thermal spray related information from the Engineering Bill of Material (EBM). Selected EBM records were extracted based on thermal spray codes (See Section 10.2). Next, corresponding records were accessed in NASSCO data bases to obtain needed information, the resulting records were sorted and reports were printed. Production Planning then downloaded this information to their corresponding production files for

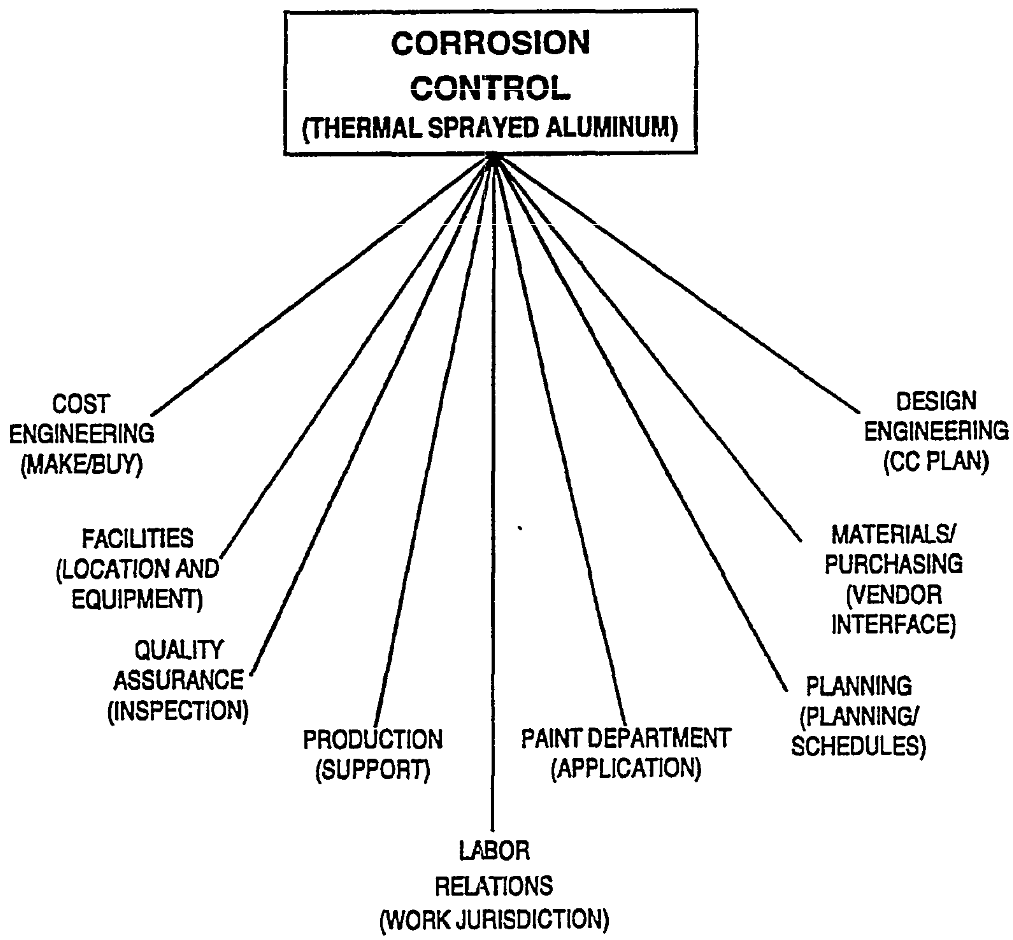


Fig. 10.4 Organizational Interface

the unit, block or zone manloading schedules. The result is an identifiable thermal spray report for Planning, Scheduling, Purchasing, Engineering and Production.

Good communication and coordination, both within and between the involved departments, are obviously vital to a successful program. This need for coordination strengthens the case for the appointment of a Corrosion Control Engineer or other project manager to oversee implementation of the TSA program as discussed earlier in this section. Without proper coordination, chances are good that some program element will "slip through the cracks" and lose visibility. Fig. 10.5 points out how the Corrosion Control Engineer can act as the central focus for the overall program.

10.5 New Construction vs Repair Work

The costs associated with thermal spray applications in a ship repair setting can differ substantially from those in new construction. Facilities applying TSA coatings to new components during original construction usually face fewer complications than those same applications during a repair availability.

Many different types of components are bid for TSA coatings under a repair work item. Some of these components have been previously TSA coated and these coatings must be identified, examined and either replaced or touched-up. Removal of existing coatings can be difficult and time consuming. Touch-up of a previously applied TSA coating can be as time consuming as removal of the entire coating.

When a previously applied TSA coating is identified, all work should stop and the Quality Assurance Department and / or local SupShip representative should be notified for disposition instructions. These disruptions require time, which is very precious during a repair availability.

The following issues should be considered during the original estimates of time and materials to apply TSA coatings for repair and new construction.

- New Construction components are always new steel that has not been in service previously; repair components may be damaged, rusted or contain old coatings.

- Interfacing with other trades for on-board work is much more difficult in repair due to the limited availability of the ship.

- New construction work-load and scheduling are relatively predictable. Repair work demands much more flexibility, often requiring immediate manpower and equipment to be mobilized to multiple job sites.

- Ships in a repair availability require more time and effort to acquire proper access letters and security checks.

- The normal ship's activities, drills and general interference can cause delays and reduce productivity.

- In repair contracts, time must be allotted to prepare a required Process Control Procedure to include checkpoints per NAVSEA standard items 009-06. For new construction, official checkpoints are normally not needed.

- Ships under repair can be located in dry dock, at pier-side or out-board of another ship pier-side. All of these locations create potential limited access for thermal spray personnel and equipment.

- During a repair availability, pier-side ship-furnished utilities such as air and electricity may not always be readily available to support the required equipment for the TSA process.

In summary, repair work is more difficult to accomplish in a cost effective manner than new construction work This is primarily due to the lack of total control of elements necessary to ensure completion of a work item within the time originally bid. Shipyards should ensure adequate contingency factors are included in the original estimate to cover some of the recognizable issues mentioned above.

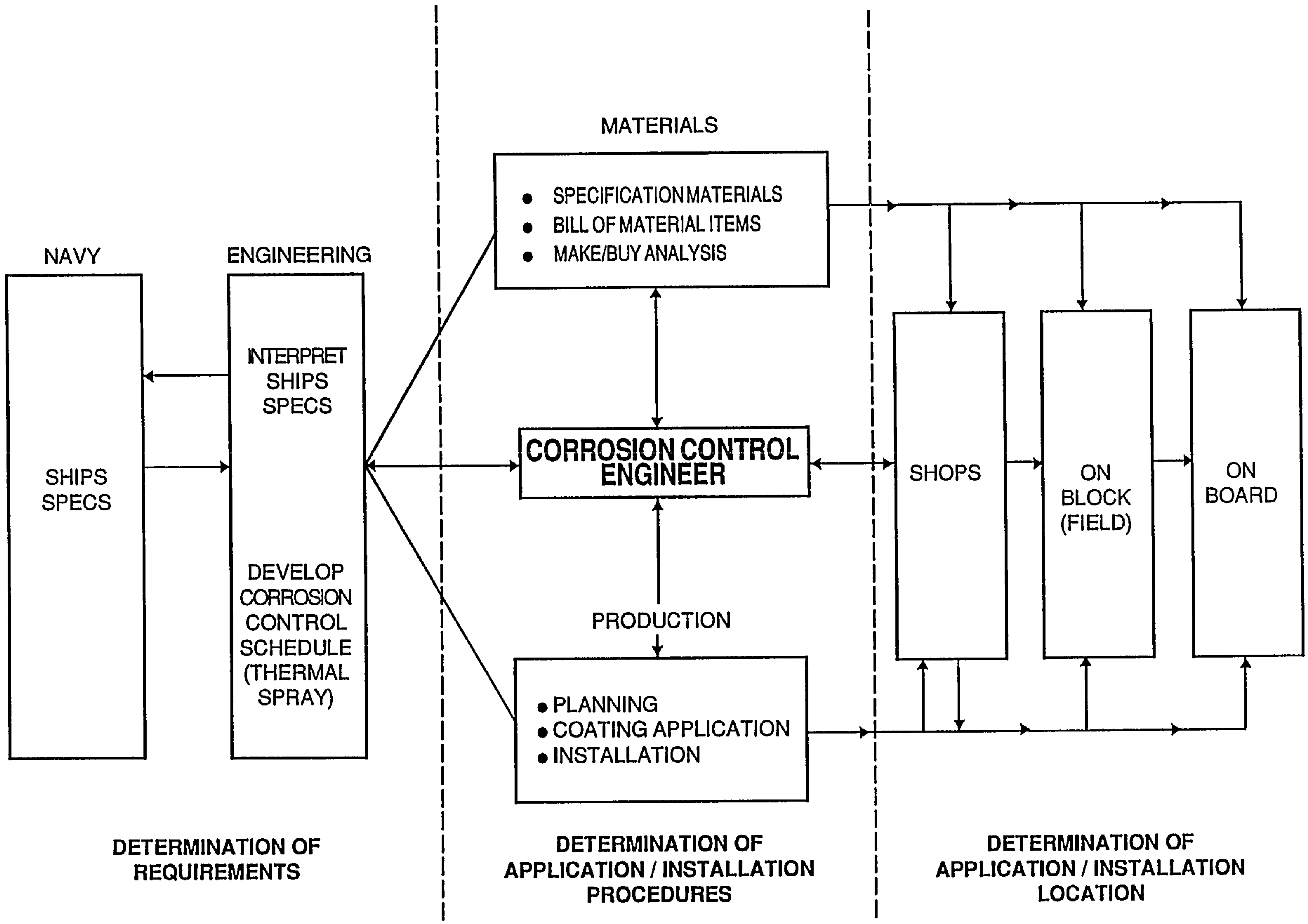


Fig. 10.5 Thermal Spray Program Overview

11. THE FUTURE OF THERMAL SPRAY IN SHIPBUILDING

11. THE FUTURE OF THERMAL SPRAY IN SHIPBUILDING

Thermal sprayed aluminum (TSA) coatings have been proven to be a cost-effective means of providing long-term corrosion protection to many shipboard components. For this reason, the U.S. Navy is expected to continue specifying the application of these coatings for future new building programs, as well as repair and overhaul contracts. The Navy is also investigating new advancements in thermal sprayed coating technology as described below.

The Navy has recently authorized the use of TSA coatings 3-4 roils thick (in place of the current 7-10mils requirement) followed by a top coating of TGIC (Triglycidal Isocyanurate) Polyester powder coating, electrostatically applied and oven-cured, for topside component applications. The new revision to DoD-STD 2138 will cover this application. The procedure provides a coating system that is superior to the existing five-coat topside paint system. The use of TGIC Polyester as a top coating eliminates the VOC environmental issues of the five coat conventional paint system and reduces the processing time of the barrier coat system from five days to two hours.

Powder coatings of TGIC Polyester alone are also being specified for many other shipboard components. For shipyards wishing to investigate the potential of setting-up powder coating equipment, there are three pieces of equipment required

- A powder coating booth and reclaiming system.
- An electrostatic powder coating application system.
- An oven capable of handling the largest size component to be processed with a maximum temperature range of 350-400 degrees F.

There are new thermal spray coating systems on the horizon. These systems are designed as duplex coatings, consisting of a TSA coating, top coated with a thermal sprayed thermal-plastic or TGIC Polyester. This system would allow large surfaces or on-board items to be coated with a superior topside corrosion control coating system, virtually eliminating the requirement for a five coat paint system. Bilges, tanks, and wetspaces, as well as interior and topside areas are being considered for potential application of these advanced coating systems.

In commercial applications, thermal spray coatings are widely accepted for corrosion control. These coatings provide long-term corrosion protection from many environments. The life cycle analysis and evaluations indicates thermal spray coatings to be extremely cost efficient.

The major oil companies such as Shell Oil and Conoco have developed comprehensive application specifications. They are convinced that thermal spray coating can out-perform conventional corrosion control methods in both submersion and splash zone environments for many of their offshore platform’s high corrosion prone areas. The potential scope of this coating work is large, including new and existing platforms. Most United States shipyards can provide the oil companies with proposals to build structural steel platfoms, and TSA coatings will be part of the corrosion control system used to protect the structure. Shipyards can benefit by having the capability to provide these coatings to support the offshore industry.

12. REFERENCES

12. **REFERENCES**

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13. GLOSSARY

13. GLOSSARY

ABRASIVE: Material used for cleaning and/or surface roughening; usually sand, crushed chilled cast iron, crushed steel grit, aluminum oxide, silicon carbide, flint, garnet or crushed slag (grit).

ABRASIVE BLASTING: See preferred term “Blasting.”

AIR CAP: A device for forming, shaping and directing an air pattern for the atomization of wire or ceramic rod.

AIR FILTER A device for removing contaminants such as water, oil, oil vapor and solid matter from the air supply.

ATOMIZATION. The operation of reducing the molten material from the end of the wire or rod into fine particles.

BACKFIRE The momentary recession of the flame into the tip, followed by immediate reappearance or complete extinguishment of the flame.

BASE METAL See preferred term “Substrate.”

BASE MATERIAL: See preferred term “Substrate.”

BERRY FORMATION. A detrimental buildup of spray material on the gun nozzle and/or in the air cap during the spraying operation.

BLASTING: A method of cleaning and/or surface roughening by a forcibly projected stream of sharp angular abrasive.

BOND: The adherence of the spray deposit to the substrate; bonds may be either mechanical or metallurgical, or a combination of both.

BOND COAT A preliminary (or prime) coat of material which improves adherence of the subsequent thermal spray deposit.

BOND STRENGTH: The stress required to separate a thermal sprayed deposit from its substrate at or near the interface, either in tension or shear.

CARRIER GAS: The gas used to carryy the powdered materials from the powder feeder or hopper to the gun.

COATING DENSITY: The ratio of the determined density of the coating to the theoretical density of the material used in the coating process. Usually expressed as percent of theoretical density.

DEPOSIT EFFICIENCY:.	The ratio (usually expressed in percent) of the weight of spray deposit to the weight of the material sprayed. (D. E.)
DEPOSITION RATE:	The weight of material deposited in a unit of time. Usually expressed as pounds per hour (lbs / hr).
ELECTRIC ARC GUN:	A thermal spraying device where the material to be sprayed is in the form of two consumable electrodes (two wires). An arc is struck and maintained between the ends of the two wires, and thus provides the heat for melting.
EXHAUST BOOTH	A mechanically ventilated, semi-enclosed area in which an air flow across the work area is used to remove fumes, gases and overspray material during thermal spraying operations.
FEED RATE:	The quantity of material through the gun in a unit of time. An interchangeable term is "Spray Rate."
FINES:	Those abrasive particles which are at the lower end of the specified mesh size.
FLAME SPRAYING:	A thermal spraying process wherein an oxy-fuel gas flame is utilized as the source of heat for melting the coating material. Compressed gas may or may not be used for atomizing and propelling the material to the work piece.
FLASHBACK:	A recession of the flame into or back of the mixing chamber of the gun.
FLASHBACK ARRESTER	A device to limit damage from a flashback by preventing propagation of the flame front beyond the point at which the arrester is installed.
FLASH COAT:	A thin coating usually less than 0.002 inches (2 mils) in thickness.
FLOWMETER:	Device for indicating the rate of gas flowing in a system.
GUN:	A term used to describe a thermal spraying device: Electric Arc Gun, Plasma Gun, Powder Flame Spray Gun, Wire Flame Spray Gun.
GUN EXTENSION:	The extension tube attached in front of the thermal spraying device to permit spraying within confined areas or deep recesses.
INTERFACE	The contact surface between the spray deposit and the substrate.
MASK	A device for protecting a surface from the effects of blasting and / or coating adherence. Masks are generally of two types: Reusable or disposable.

MASKING:	The method of protecting the areas adjacent to the areas to be thermal sprayed or blasted, to prevent adherence of a coating or surface roughening.
MECHANICAL BOND:	The adherence of thermal sprayed deposit to a roughened surface by the mechanism of particle interlocking.
METALLURGICAL BOND:	The adherence of a thermal sprayed coating to a surface by a diffusion of atoms across the interface.
NOZZLE:	The outlet tip of a thermal spray gun.
PASS:	A single progression of the thermal spray device across the surface of the substrate.
POWDER FEEDER.	A device for supplying powdered materials to thermal spraying equipment.
POWDER COMBUSTION SPRAYING:	A method of flame spraying wherein the material to be sprayed is in powder form.
POWDER COMBUSTION SPRAY GUN:	A flame spraying device where an oxy-fuel gas flame provides the heat and the material to be sprayed in powder form.
POWDER METALLIZING:	See preferred term 'Powder Flame Spraying."
PREHEATING:	The application of heat to the base material before spraying.
SEAL COAT:	Material applied to infiltrate the pores of a thermal spray deposit.
SPALLING:	The flaking or separation of a sprayed coating.
SPRAY DEPOSIT:	The coating applied by any of the thermal spray methods.
SPRAY RATE:	An interchangeable term with "Feed Rate." See "Feed Rate."
SPRAYING SEQUENCE	The order in which different passes of similar or different materials are applied in a planned relationship, such as overlapping, super-imposed, or at certain angles.
SUBSTRATE:	Any material upon which a thermal sprayed coating is deposited.
SURFACE PREPARATION:	The operation necessary to prepare a surface for thermal spraying.
SURFACE ROUGHENING	A group of procedures for producing irregularities on the surface to be thermal sprayed.
THERMAL SPRAYING:	A group of processes wherein finely divided metallic or non-metallic materials are deposited in a molten or semi-molten

condition to form a coating. The coating material may be in the form of powder, ceramic, rod, wire or molten materials.

UNDERCOAT:	A deposited coat of material which acts as a substrate for a subsequent thermal sprayed deposit. See "Bond Coat" and "Flash Coat."
WATER WASH:	The forcing of exhaust air and fumes from a spray booth through water so that the vented air is free of thermal sprayed particles or fumes.
WIRE COMBUSTION SPRAYING:.	A method of flame spraying wherein the metallic material to be sprayed is in wire form.
WIRE COMBUSTION SPRAY GUN:	A flame spraying device where an oxy-fuel gas flame provides the heat and the metallic material to be sprayed is in wire form.
WIRE SPEED:	The length of wire, sprayed in a unit of time.
WIRE STRAIGHTENER	A fixture for taking the cast out of coiled wire to enable it to be easily fed into the gun.

APPENDIX A:
SURVEY RESULTS

APPENDIX A

SURVEY RESULTS

SHIPYARD SURVEY

The first phase of the project consisted of sending survey forms to several shipyards worldwide to obtain information on background, work methods and application rates for thermal sprayed aluminum. The following shipyards participated in the survey

- Avondale Shipbuilding, New Orleans, LA
- Bath Iron Works, Bath, ME
- Ingalls Shipbuilding, Pascagoula, MI
- NASSCO Shipbuilding, San Diego, CA
- Norfolk Shipbuilding, Norfolk, VA
- Pearl Harbor NSY, Pearl Harbor, HI
- Puget Sound NSY, Bremerton, WA
- Subic Bay Repair, Subic Bay, PI
- SRF Yokosuka, Japan

A sample shipyard survey form is shown in Fig. A-1. The top portion of the form (Part A) requests general information on background, work processes and equipment. The bottom portion (Part B) asks for production rate information relative to various typical components being thermal sprayed in different environments. There is also space on the form for general remarks and other comments.

A summary of shipyard survey results is presented in Tables A-2 and A-3. Table A-2 summarizes responses from Part A, General Information, and Table A-3 is a summary of Part B, Production Rates.

Table A-2 points out that most yards surveyed have been involved in thermal sprayed aluminum work for nearly ten years, whereas NASSCO, with about three years experience, is the newcomer. The yards are evenly divided in the category of primary type of work - new construction or repair. Every yard except Puget Sound NSY, favors the use of the combustion wire gun. On average, 65% of the work is accomplished in a shop setting. It should also be noted that an average of about 4% rework or coating repair was reported for all yards. Most of the rework is due to handling damage. Another source of rework is repair of weld quality defects that require reblasting and sometimes recoating weld areas.

The Production Rate Summary (Table A-3) shows the time difference to accomplish work in a shop setting as opposed to on-block (field) or on-board ship work The data generally indicates a wide range of times reported by different yards (least time vs. most time). To calculate more meaningful averages, the least and highest times in each category were disregarded. Also, preparation times reported vary greatly since yards may have different interpretations of the work elements included in this category. This rate data should be used primarily as a guide to comparisons between types of components and work location, rather than an indicator of actual work rates.

VENDOR/SUBCONTRACTOR SURVEY

A separate survey form was sent to thermal spray equipment manufacturers or suppliers to obtain information on recommended equipment types and costs, including data regarding equipment capabilities. A sample vendor survey form is shown in Fig. A-4. The cost for each manufacturer of arc and combustion wire and powder systems are relatively the same, and their capabilities are comparable. In order to determine the system that would best fit your needs, look for equipment dependability, replacement part costs and the technical support you can expect from a supplier.

A summary of the vendor survey responses is presented in Tables A-5 and A-6. Table A-5 provides a summary of data and approximate costs for typical thermal spray gun systems currently on the market. Table A-6 lists the various thermal spray support equipments available from several suppliers, along with approximate costs. These costs are meant to be a guide to provide an order of magnitude for the listed types of equipment. Refer to Appendix B for a more detailed list of equipment and consumable supplies.

THERMAL SPRAY SURVEY

COMPANY: ____________ CONTACT: ____________ PHONE NO.: ____________

A. GENERAL INFORMATION - MANNING AND EQUIPMENTS

1. How long have you had an established thermal spray program? ____________
2. How many people are usually employed in the thermal spray group (operators and supervision)? ____________
____
3. Do you accomplish new construction thermal spray work? YES ______ NO ______
Repair ? YES ______ NO ______ What percentage? New Construction ______% Repair ______%
4. What types of equipment do you use for spraying aluminum? How many pieces of equipment do you have?

	QUANTITY	% OF TIME IN USE
Wire Guns ______	______	______
Electric Arc ______	______	______
Powder ______	______	______

5. How many pounds per month of aluminum do you spray? ____________
6. What percentage of your work (man hours) is in shop? ______% On-board ______% On-block ______%
7. What is your approximate percentage of rework/repair of flame sprayed coatings? ____________%

B. MAN HOURS PER JOB

1. What are your average man hours for the following components?

COMPONENT	IN-SHOP			ON-BLOCK OR ON-BOARD SHIP		
	PREP.	BLAST	SPRAY	PREP.	BLAST	SPRAY
6" Globe Valve						
Wt Door 30" x 60"						
Small Foundation 60 sq. ft.						
Large Foundation 100 sq. ft.						
Bitts/Chocks						
Other ______ sq. ft. ______						

2. Do you have a standard scale or rate which is bid for the thermal spraying of aluminum? ____________
____

REMARKS / OTHER PROBLEMS / SUGGESTIONS: ____________
____
____
____

REFERRALS: ____________

Fig. A-1. Sample Shipyard Survey Form

SHIPYARD	YEARS IN BUSINESS	GROUP SIZE	WORK TYPE (%)		GUN TYPE MOST OFTEN USED	WORK LOCATION (%)		AVG. LBS/MO. OF ALUMINUM SPRAYED
			NEW CONST.	REPAIR		IN SHOP	FIELD/ONBOARD	
AVONDALE SHIPBUILDING	9	10	70	30	COMBUSTION WIRE	70	30	1200
BATH IRON WORKS	10	24	90	10	COMBUSTION WIRE	20	80	800
INGALLS SHIPBUILDING	10	19	80	20	COMBUSTION WIRE	45	55	450
NASSCO SHIPBUILDING	3	6	98	2	COMBUSTION WIRE	90	10	100
NORFOLK SHIPBUILDING	9	14	40	60	COMBUSTION WIRE	20	80	100
PEARL HARBOR NAVAL SHIPYARD	10	7	40	60	COMBUSTION WIRE	90	10	No Response
PUGET SOUND NAVAL SHIPYARD	14	12-15	20	80	ELECTRIC ARC	60	40	600
SUBIC BAY SHIP REPAIR	11	10	0	100	COMBUSTION WIRE	100	0	No Response
S.R.F. YOKOSUKA (JAPAN)	10	19	50	50	COMBUSTION WIRE	90	10	5

Table A-2. Thermal Spray Survey Response Summary

SHOP WORK										
COMPONENT	PREPARATION			BLAST			SPRAY			TOTAL
	Least Time	Average	Highest	Least Time	Average	Highest	Least Time	Average	Highest	Avg. Time
6" Valve	15 min.	53 min.	1½ hr.	25 min.	45 min.	1 hr.	25 min.	40 min.	1 hr.	2¼ hr.
WT Door	30 min.	1½ hr.	4 hr.	1½ hr.	2 hr.	4 hr.	30 min.	2¼ hr.	4 hr.	5¾ hr.
Small Fdn.	30 min.	47 min.	1½ hr.	1 hr.	1¾ hr.	3 hr.	1 hr.	2 hr.	3 hr.	4½ hr.
Large Fdn.	30 min.	1¼ hr.	2½ hr.	1½ hr.	3 hr.	4½ hr.	2 hr.	3¼ hr.	4 hr.	7½ hr.
Bitt/Chocks	20 min.	40 min.	1 hr.	1 hr.	1½ hr.	2 hr.	45 min.	1½ hr.	2 hr.	3¾ hr.
ON-BLOCK OR ON-BOARD WORK										
COMPONENT	PREPARATION			BLAST			SPRAY			TOTAL
	Least Time	Average	Highest	Least Time	Average	Highest	Least Time	Average	Highest	Avg. Time
WT Door	4 hr.	6 hr.	8 hr.	4 hr.	4¾ hr.	6 hr.	2 hr.	3½ hr.	5 hr.	14¼ hr.
Small Fdn.	1 hr.	3¼ hr.	8 hr.	45 min.	2½ hr.	6 hr.	30 min.	2 hr.	4 hr.	7¾ hr.
Large Fdn.	1 hr.	4½ hr.	12 hr.	1½ hr.	4 hr.	8 hr.	1¼ hr.	3½ hr.	6 hr.	12 hr.
Bitt/Chocks	1 hr.	1¼ hr.	2 hr.	1½ hr.	1¾ hr.	2 hr.	1 hr.	1¼ hr.	2 hr.	4¼ hr.

Table A-3. Production Rate Summary

VENDOR SURVEY QUESTIONS	Company Name: ______ Address: ______
	Contact: ______ Phone No.: ______

Please list the types of equipment you normally supply thermal spray facilties in support of Dod-STD 2l38. If you supply more than one type of thermal spray system, list them in order of effectiveness to enable a facility to process the following example:

EXAMPLE: WATERTIGHT DOOR OR EQUIPMENT FOUNDATION

A steel component not to exceed 150 sq. ft. with angles (which would require an angle type spray head). All surfaces to be coated except those areas which are required to be masked per Dod-STD 2138 (SH). This component could be processed either in a shop environment or on-board ship.

Thermal Spray Equipment Type/ Model No.	Recommended for On.Board/Shop		Spray Rate LbsJHr.	Deposit % Efficiency	Extension & Angle Head Cap.	(YIN)	Approx. System cost	Daily Maint. **Man** Hrs. Req.

Comments: ______

Please list and describe any other equipment you normally supply for abrasive blasting, grit recovery, dust collection, masking, Q.A. testing, or custom made devices which would support the thermal spray process. If possible, please supply approximate cost for this equipment.

g A-4. Sample Vendor Survey Form

VENDOR	THERMAL SPRAY GUN TYPE/MODEL NO.	RECOMMENDED FOR ON-BOARD/SHOP		SPRAY RATE, LBS./HR.	DEPOSIT EFFICIENCY, %	EXTENSION & ANGLE AIR CAP (Y/N)		APPROX. SYSTEM COST (RANGE)	DAILY MAINTENANCE TIME REQ'D.
Hobart Tafa Technologies	8830 Electric Arc	Yes	Yes	35	70	Y	Y	$14,000-16,000	15 min.
Eutectic Corp.	3000 Terodyn Combustion Powder	Yes	Yes	35	90	Y	Y	$9,000-12,000	15
Perkin-Elmer Metco Div.	11E/12E Combustion Wire	Yes	Yes	15/16	90-95	Y	Y	$6,000-7,000	30
	5PII/6PII Combustion Powder	Yes	Yes	15/15	85	Y	Y	$9,000-12,000	15
	4RG/6RG Electric Arc	Yes	Yes	10/14	70-80	N	N	$12,000-15,000	15
Miller Thermal Inc.	BP400 Electric Arc	Yes	Yes	3-18	85-95	N	N	$12,500-14,000	10
	TJ5 Combustion Wire	Yes	Yes	5-10	75-85	Y	Y	$6,000-7,000	30
Hardface Alloy, Inc.	TJ5 Combustion Wire	Yes	Yes	5-10	75-85	Y	Y	$6,000-7,000	30

Table A-5. Thermal Spray Gun Summary

EQUIPMENT DESCRIPTION	COST RANGE	SUPPLIERS
Dust Collector (Dry)	$4.00/cfm Includes installation and cost/cfm	Hobart Tafa Miller Thermal Metco Perkin Elmer Flame Spray Leasing
Dust Collector (Wet)	$7,500 - $12,000	Hobart Tafa Miller Thermal Metco Perkin Elmer Flame Spray Leasing
Blasting Cabinets	$4,000 - $9,000	Hardface Alloys Flame Spray Leasing
Abrasive Blast Equipment	$3,000 - $6,000	JG Systems Flame Spray Leasing
Vacuum Recovery System	$20,000 - $40,000	JG Systems Flame Spray Leasing
Containerized Blast and Spray Systems	$145,000 - 180,000	Flame Spray Leasing
Portable Blast Recovery and Dust Collection Systems	$70,000 - 90,000	JG Systems Flame Spray Leasing
Air Dryers	$5,000 - 16,000	Flame Spray Leasing
Aluminum Wire 1/8" or smaller	$3.00 - $4.00/lb.	Metco Perkin Elmer Miller Thermal Hardface Alloys Hobart Tafa
Masking Materials	$20 - $40/ 36 yd. roll	Metco Perkin Elmer Hardface Alloys Flame Spray Leasing
Abrasive Grit	$0.40 - $1.00/lb.	Metco Perkin Elmer Flame Spray Leasing

Table A-6. Thermal Spray Support Equipment Summary

APPENDIX B:
SUPPLIERS

APPENDIX B

EQUIPMENT AND CONSUMABLES SUPPLIER LIST

Following is a partial list of suppliers who can provide equipment, consumables or services to support a thermal spray facility. The categories are in equipment and consumable alphabetical order. An index to suppliers is provided after the list.

AIR DRYER / RELATED EQUIPMENT
Refrigerative, Regenerative, After Coolers, Water Traps, Auto Drain Valves, Oil Filters.

Air-Dry Corp. of America	Ingersoll-Rand Co.	Zeks Air Drier Corp.
Glenro, Inc.	Pall Pneumatic	Zurn Industries, Inc.
Hankinson Corporation	Van Air Systems, Inc.	

COMPRESSORS (stationary/portable)
Reciprocating, Rotary and Screw

Carlson & Beauloye	Gardner Denver	Keco, Ind.
CompAir-Kellogg, Inc.	Ingersoll-Rand Co.	Sullair Corporation
CompAir Mako, Inc.	**JOY** Manufacturing	

CONSUMABLES: Aluminum Oxide Grit
Mesh sizes from 20 to 160 Grit

Flame Spray Leasing	Metco Perkin-Elmer
Fusco Abrasive Systems, Inc.	Mission Abrasives

CONSUMABLES: Aluminum Wire (spool/coils)
11 Ga., 14 Ga., 1/8", 3/16" Diameters

Flame Spray Leasing	Hobart Tafa Technologies	Miller Thermal, Inc.
Hardface Alloys	Metco Perkin-Elmer	

CONSUMABLES: Aluminum Powder

Eutectic Corporation	Hardface Alloys	Miller Thermal, Inc.
Flame Spray Leasing	Metco Perkin-Elmer	

CONSUMABLES: Bend Test Coupons
2" x 3" x .050" thick plates

Flame Spray Leasing

CONSUMABLES: Profile Tape

Flame Spray Leasing	Testex, Inc.

GRIT BLAST & RECOVERY EQUIPMENT / BLASTING DUST COLLECTORS

CAB International
Clemco Industries Corp.
Dee-Blast Corporation
Donaldson Company, Inc.
Empire Corporation
Flame Spray Leasing
Hardface Alloys
Industrial Cleaning Machine
Ingersoll-Rand Company
IPEC
J.G. Systems, Inc.
Kelco
Poly Griffin
Schmidt Manufacturing, Inc.
Vacu-Blast

PORTABLE CONTAINERIZED SYSTEMS FACILITIES AND SKIDS

Flame Spray Leasing
J.G. Systems, Inc.

QUALITY ASSURANCE EQUIPMENT
Magnetic Thickness Gage, Surface Pyrometer, Temperature/Humidity Gage, Dew Point Chart, Testex Profile Test Kit, Press-O-Film

Elektro-Physik
EXTECH Instruments Corp.
KTA-Tator, Inc.
Omega Engineering, Inc.
Testex, Inc.
United Calibration Corp.

SAFETY EQUIPMENT
Safety Glasses, Ear Plugs, Fire Extinguisher, Air Breather Helmet, Air Breather Filter Safety Belts, Hard Hats, Knee Pads, Blasting Leathers, Safety Shoes

Clemco Industries Corp.
Flame Spray Leasing
Kelco
Metco Perkin-Elmer
Miller Thermal, Inc.

SPRAY EQUIPMENT, Combustion Powder / Wire

Eutectic Corporation
Flame Spray Leasing
Metco Perkin-Ehner
Miller Thermal, Inc.

SPRAY EQUIPMENT, Arc Wire

Hobart Tafa Technologies
Metco Perkin-Elmer
Miller Thermal, Inc.
Thermion Metalizing Systems

WET TSA COLLECTION EQUIPMENT
Water Wash Spray Booths

Devilbiss Company
Binks Manufacturing
Flame Spray Leasing
Miller Thermal, Inc.

DRY TSA COLLECTION EQUIPMENT
Cyclones, Bag Houses, Cartridge Collectors, HEPA Filters, Blowers

American Air Filter (AAF)
Environmental Control Co.
Flame Spray Leasing
Hobart Tafa Technologies
Metco Perkin-Elmer
Miller Thermal, Inc.
Tent Donaldson Co.

INDEX TO SUPPLIERS

Air-Dry Corp. of America
19338 Londelius Street
P.O. Box 826
Northridge, CA 91328
PH: (818) 886-7323
FAX: (213) 873-2865

American Air Filter (AAF)
P.O. Box 35690
Louisville, KY 40232
PH: (502) 638-0011
FAX: (502) 637-0148

Binks Manufacturing
2553 South Garfield Avenue
Los Angeles, CA 90040
PH: (213) 888-9955
FAX: (213) 721-6571

CAB International
P.O. Box 309
Kent, WA 98035
PH: (800) 222-8843
FAX: (206) 251-8683

Carlson & Beauloye
2143 Newton Avenue
San Diego, CA 92113
PH: (619) 234-2256
FAX: (619) 234-2095

Clemco Industries Corp.
1 Cable Car Drive
Washington, MO 63090
PH: (314) 239-4300
FAX: (800) 726-7559

CompAir-Kellogg, Inc.
Route 58 West
Independence, VA 24348
PH: (800) 422-1721
FAX: (703) 773-2645

CompAir Mako, Inc.
1634 S.W. 17th Street
P.O. Drawer 1630
Ocala, FL 32678
PH: (904) 732-2268
Telex: 56-236

Dee-Blast Corporation
3039 Johnson Road
Stevensville, MI 49127
PH: (800) 253-3661

Devilbiss Company
8205 S. Cass Ave. #162
Darian, IL 60559
PH: (708) 969-0440
FAX: (708) 969-1397

Donaldson Company, Inc.
Torit Division
P.O. Box 1299
Minneapolis, MN 55440
PH: (612) 887-3900
FAX: (612) 887-3377

Elektro-Physik
778 West Algonquin Rd.
Arlington Hts., IL 60005
PH: (800) 782-1506
FAX: (708) 437-0053

Empire Corporation
2101 West Cabot Blvd.
Langhome, PA 19047
PH: (215) 752-8800
FAX: (215) 752-9373

Environmental Control Co.
P.O. Box 3556
Vista, CA 92085
PH: (619) 727-9814
FAX: (619) 727-7650

Eutectic Corporation
40-40 172nd Street
Flushing, NY 11358
PH: (800) 221-1433
FAX: (708) 932-9466

EXTECH Instruments, Corp.
150 U-Bear Hill Rd.
Waltham, MA 02154
PH: (617) 890-7440
FAX: (617) 890-7864

Flame Spray Leasing
4674 Alvarado Canyon Road
San Diego, CA 92120
PH: (619) 283-2007
FAX: (619) 283-5467Fusco

Abrasive Systems, Inc.
301 W. 28th Street, Suite K
National City, CA 92050
PH: (619) 477-0069
FAX: (619) 477-0751

Gardner Denver
1800 Gardner Expressway
Quincy, IL 62301
PH: (217) 222-5400
FAX: (217) 223-5897

Glenro, Inc.
39 McBride Ave. Ext.
Paterson, NJ 07501
PH: (800) 922-0106
FAX: (201) 279-9103

Hankinson Corporation
1000 Philadelphia Street
Canonsburg, PA 15317
PH: (800) 638-2000
FAX: (412) 553-6268

Hardface Alloys
8351 Secura Way
Santa Fe Springs, CA 90670
PH: (310) 945-5477
FAX: (310) 696-1868

Hobart Tafa Technologies
146 Pembroke Road
Concord, NH 03301
PH: (603) 224-9585
FAX: (603) 225-4342

Industrial Cleaning Machine
10640 South Garfield
Southgate, CA 90280
PH: (800) 421-3521
FAX: (213) 773-4982

INDEX TO SUPPLIERS (cont'd.)

Ingersoll-Rand Co.
670 L Street, Suite D
Chula Vista, CA 92011
PH: (619) 425-0650
FAX: (619) 425-0951

Ingersoll-Rand Company
200 Chestnut Ridge Rd.
P.O. Box 8738
Woodcliff Lake, NJ 07675
PH: (800) 847-4041

IPEC
P.O. Box 996
Quonset Point
Davisville Industrial Park
North Kingstown, RI 02854
PH: (401) 295-8802
FAX: (401) 294-6477

JG Systems, Inc.
P.O. Box 840247
Houston, TX 77284
PH: (713) 466-4322
FAX: (713) 466-9038

Joy Manufacturing
301 Grant Street
Pittsburgh, PA 15219
PH: (415) 562-4500
FAX: (412) 562-4470

Keco, Ind.
7375 Industrial Rd.
Florence, KY 41042
PH: (606) 525-2102
FAX: (606) 525-6667

Kelco
2145 East Belt Street
San Diego, CA 92113
PH: (619) 292-4900
FAX: (619) 236-9757

KTA-Tator, Inc.
RIDC Park West
115 Technology Drive
Pittsburgh, PA 15275
PH: (412) 788-1300
FAX: (412) 788-1306

Metco Perkin-Elmer
1101 Prospect Avenue
Westbury, NY 11590
PH: (516) 334-1300
FAX: (516) 334-1938

Metco Perkin-Elmer
Downey Division
12000 Woodruff Ave., Ste. E
Downey, CA 90241
PH: (213) 803-1060
FAX: (213) 803-6827

Miller Thermal, Inc.
555 Communication Drive
Appleton, WI 54912
PH: (414) 731-6884
FAX: (414) 734-2160

Miller Thermal, Inc.
555 Communication Drive
Appleton, WI 54912
PH: (414) 731-6884
FAX: (414) 734-2160

Mission Abrasives
9292 Activity Road
San Diego, CA 92126
PH: (619) 566-6700
FAX: (619) 477-0751

Omega Engineering, Inc.
One Omega Drive, Box 4047
Stanford, CT 06907
PH: (203) 359-7874
FAX: (203) 359-7900

Pall Pneumatic
4647 S.W. 40th Ave.
Ocala, FL 32674
PH: (904) 237-1220
FAX: (904) 854-1402

Poly Griffin
907 Cotting Lane
Vacaville, CA 95688
PH: (800) 666-1115
FAX: (707) 447-7036

Schmidt Manufacturing, Inc.
P.O. Box 37
Fresno, TX 77545
PH: (713) 431-0851
FAX: (713) 431-1717

Sullair Corporation
3700 E. Michigan Blvd.
Michigan City, IN 46360
PH: (219) 879-5451
FAX: (219) 874-1252

Testex, Inc.
P.O. Box 867
Newark, DE 19715
PH: (302) 731-5693
FAX: (302) 368-4568

Thermion Metalizing Systems
P.O. Box 2136
Silverdale, WA 98383-2136
PH:/FAX: (206) 698-1539

Torit Donaldson Co.
P.O. Box 1299
Minneapolis, MN 55440
PH: (612) 887-3900
FAX: (612) 887-3054

United Calibration Corp.
5802 Engineer Drive
Huntington Beach, CA 92649
PH: (714) 638-2322
FAX: (714) 897-8496

Vacu-Blast
P.O. Box 286
Hwy. 77 North
Harington, KS 67449
PH: (800) 255-7910
FAX: (913) 258-2584

Van Air Systems, Inc.
2950 Mechanic Street
Lake City, PA 16423
PH: (814) 774-2631
FAX: (814) 774-3482

INDEX TO SUPPLIERS (cent'd.)

Zeks Air Drier Corp.
Malvern Industrial Park
P.O. Box 396
Malvem, PA 19055
PH: (215) 647-1600
FAX: (215) 647-9199

Zurn Industries, Inc.
General Air Division
1335 West 12th Street
Erie, PA 16501
PH: (814) 453-3651
Telex: 91-4428

APPENDIX C: SPECIFICATIONS

APPENDIX C

GENERAL SPECIFICATIONS AND SAFETY STANDARDS

GENERAL SPECIFICATIONS

These specifications cover the procedures, equipments and consumables required to accomplish thermal sprayed aluminum coatings.

Federal Specifications

O-T-620 - 1,1,1 -Trichloromethane, Technical Inhibited (Methyl Chloroform).

BB-A-106 - Acetylene, Technical, Dissolved.

BB-O-925 - Oxygen, Technical, Gas and Liquid.

lT-T-548 - Toluene, Technical.

Military Specifications

DoD-STD 2138 (SH) - Metal Sprayed Coating Systems for Corrosion Protection Aboard Naval ships.

MIL-M-3800 - Metallizing Outfits (Wire Gas), Guns and Accessories.

MIL-W-6712 - Wire; Metallizing.

MIL-P-23377 - Primer Coatings: Epoxy-Polyamide, Chemical and Solvent Resistant.

MIL-P-24441 - Paint, Epoxy-Polyamide, General Specification for.

MIL-P-24441/l - Paint, Epoxy-Polyamide, Green Primer, Formula 150.

MIL-P-24441/2 - Paint, Epoxy-Polyamide, Exterior Topcoat, Haze Gray, Formula 151.

DOD-P-24555 - Paint, Ahuninum, Heat-Resisting (650 C), Low-Emissivity (0.40 or Less) (Metic).

MIL-M-80141 - Metall.izing Outfits, Powder-Gas, Guns and Accessories.

MIL-M-80226 - Metallizing System, Wire, Electric Arc, Guns and Accessories.

MIL-P-83348 - Powder, Plasma Spray.

PUBLICATIONS:

NAVAL SEA SYSTEMS COMMAND:

NAVSEA S9086-VD-STM-OO0. Chapter 631- Preservation of Ships in Service (Surface Preparation and Painting).

NAVSEA S9086-CH-STM-030. Chapter 074, Voh.une 1- Welding and Allied Processes.

NAVSEA S9086-CH-STM-030. Chapter 074, Volume 3- Gas Free Engineering.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM):

C 633- Adhesion or Cohesive Strengths of Flame-Sprayed Coating, Test Method For.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

AMERICAN WELDING SOCIETY (AWS):

A3.O - Welding Terms and Definitions Including Terms for Brazing, Soldering, Thermal Spraying, and Thermal Cutting.

C2.1 - Recommended Safe Practices for Thermal Spraying.

(Application for copies should be addressed to the American Welding Society, 2501 Northwest 7th Street, Miami, FL 33125).

STEEL STRUCRES PAINTING COUNCIL (SSPC):

SSPC No. 5- Volume 2, Section 2, White Metal Blast Cleaning.

(Application for copies should be addressed to the Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA 15213).

DEPARTMENT OF LABOR:

Code of Federal Regulations, Title 29 Part 1910- Occupational Safety and Health Standards.

(Application for copies should be addressed to the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.)

SAFETY STANDARDS

All safety information is intended as educational material, not for use as a mandatory code or regulation. Standards and other documents listed in this section refer to the latest edition.

- Occupational Safety and Health Act Standards (29CFR 1910), available from the Superintendent of Documents, U.S. Government Printing Office.
- Ventilation Control of Grinding, Polishing, and Buffing of Metals, ANSI Z43.1, available from American National Standard Institute.
- Safety in Welding and Cutting, ANSI Z49.1, available from Welding Society.
- Standard Practices for Occupational and Educational Eye and Face Protection, ANSI **Z87.1, available** from American National Standards Institute.
- Standard Practices for Respiratory Protection, ANSI Z88.2, available from American National Standards Institute.
- Safety Requirements for Industrial Head Protection, ANSI ZA89.1, available from American National Standards Institute.
- National Electrical Code, ANSI/NFPA 70-1979, available from National Fire Protection Association, updated annually.
- Safe handling of Compressed Gases, CGA Pamphlet P-1, available from the Compressed Gas Association.
- Oxygen, CGA Pamphlet G-4, available from the Compressed Gas Association.
- Safe Practices for Welding and Cutting Containers that have held combustibles, AWS A6.0, available from American Welding Society.
- Safety Release Device Standards - Cylinders for Compressed Gases, CGA Pamphlet S1.1, available from the Compressed Gas Association.
- Safety Release Device Standards - Cargo and Portable Tanks for Compressed Gases, CGA Pamphlet S1.2, available from the Compressed Gas Association.
- Power Piping, ANSI B31.1, available from the American National Standards Institute.
- Acetylene, CGA Pamphlet G-1, available from the Compressed Gas Association.
- Oxygen-Fuel Gas Systems for Welding and Cutting, ANSI/NFPA 51, available from the National Fire Protection Association.
- Standards for Ftie Prevention in Use of Cutting and Welding Processes, ANSI/NFPA 51B, available from the National Fire Protection Association.
- Standard for the Storage and Handling of Liquified Petroleum Gases, ANSI/NFPA 58, available from the National Fire Protection Association.

APPENDIX D:
OPERATOR TEST

APPENDIX D

THERMAL SPRAY OPERATOR

CERTIFICATION

TEST

Operator's Name ______________________________

Badge Number ______________________________

Social Security Number ______________________________

SCORE SHEET

EQUIPMENT ____________________

Total possible points -22 pts.

PROCESSING ____________________

Total possible points -32 pts.

QUALITY ASSURANCE ________________

Total possible points -8 pts.

HEALTH AND SAFETY ________________

Total possible points -14 pts.

MULTIPLE CHOICE QUESTIONS

Total possible points -11 pts.

GENERAL **QUESTIONS** ________________

Total possible points -47 pts.

TOTAL SCORE _____________

POSSIBLE SCORE _______________

GRADE PERCENTAGE _________________

EQUIPMENT

The equipment listed below can be categorized into one of the three groups designated by the letter A, B or C. Write in the appropriate group letter (A, B or C) next to the equipment listed.
1 POINT PER ANSWER.

A. Equipment to clean, dry and compress air.
B. Blasting equipment.
c. Spraying equipment (Thermal Spraying).

Example: __B__ 1. Blast Pot (This would fall into Category 'B' because it would be used for blasting.)

_____ 1. Blast Pot (example)
_____ 2. Blasting Gloves
_____ 3. Air Pressure Regulator
_____ 4. Water Separator
_____ 5. Oxy-Acetylene Hose (from control console to gun)
_____ 6. Air Fed Helmet
_____ 7. Metal Spray Gun
_____ 8. Control Console
_____ 9. Air Compressor
_____ 10. Wire Feed Rack
_____ 11. After Cooler
_____ 12. Oxy-Acetylene Hose (from bottles to console)
_____ 13. Air Line (from dryer to console)
_____ 14. Air Dryer
_____ 15. Air Line (from console to gun)
_____ 16. Oil Separator
_____ 17. Aluminum Oxide Grit
_____ 18. Blast Line and NozzIe
_____ 19. Oxy-Acetylene Gauges
_____ 20. Dead Man Line and Switch
_____ 21. Aluminum Wire
_____ 22. Air Line (from breather filter to air fed helmet)

PROCESSING

Describe in your own words the purpose and procedures of each of the following steps in the Thermal Spray process. If you need more space use the back of this page.
4 POINTS PER ANSWER.

1. Cleaning - ______________________________

2. Masking - ______________________________

3. Strip Blasting - ______________________________

4. Anchor Tooth Blasting - ______________________________

5. Preheating - ______________________________

6. Spraying - ______________________________

7. Demasking - ______________________________

8. Sealing - ______________________________

QUALITY ASSURANCE

Match Quality Assurance equipment with the appropriate description of each item listed below.
1 POINT PER ANSWER.

_______ 1. Press-o-film

_______ 2. Elecometer (Mil Gauge)

_______ 3. Bend Test

_______ 4. Pyrometer

_______ 5. Metallography

_______ 6. Tensile Test

_______ 7. Visual Inspection

_______ 8. Dial Indicator

A. Testing procedure that can be accomplished easily and quickly to determine acceptable bonding of the coating to the test panel.

B. Instrument used to determine anchor tooth profile height.

c. Compressible material that produces an exact replica of the anchor tooth profile so that it can be measured.

D. One of the most simple and yet effective Quality Assurance procedures at your disposal.

E. Measuring device used to determine part temperatures.

F. Used to determine coating thickness.

G. Magnified picture of a cross section of a sprayed test panel used to examine coating integrity.

H. Testing procedure that involves gluing a test piece to a sprayed test panel and mechanically pulling the two apart to determine bond strength.

HEALTH AND SAFETY

List all health and safety requirements for the Thermal Sprayed Aluminum process.
2 POINTS PER ANSWER.

EQUIPMENT MAINTENANCE - ______________________________

USE OF EQUIPMENT - ______________________________

FIRE AND EXPLOSION HAZARD - ______________________________

GAS CYLINDER PRECAUTIONS - ______________________________

GASES - ______________________________

RESPIRATORY HAZARDS - ______________________________

PERSONAL PROTECTION - ______________________________

MULTIPLE CHOICE

1 POINT PER ANSWER.

1. CORROSION ISA PROCESS

   A. that is not important in today's Navy.
   B. where metals degrade as a result of reaction to their environment.
   c. where metals upgrade because of the environment.
   D. of concern to surface ships only.

2. WHICH OF THE FOLLOWING IS CHARACTERISTIC OF A SACRIFICIAL COATING?

   A. a lower galvanic number than the metal being protected.
   B. bond strength less than 1500 psi.
   c. a higher galvanic number than the metal being protected.
   D. porosity.

3. THE PROCESS BY WHICH ALL METALS DEGRADE AS A RESULT OF REACTION WITH THE ENVIRONMENT IS CALLED?

   A. breakdown
   B. galvanic corrosion
   c. corrosion
   D. all of the above

4. A WIRE-SPFM.YED ALUMINUM COATING

   A. must be bonded to a 2-3 mil electrolyte.
   B. is a sacrificial coating to protect steel.
   c is a bonding control for thickness.
   D. should be used only in below deck spaces.

5. WHICH OF THE FOLLOWING STATEMENTS BEST DESCRIBES GALVANIC CORROSION?

   A. the process by which all metals degrade.
   B. the result of two dissimilar metals corroding through an electrolyte.
   c. protection of the surface using WSA.
   D. the elimination of rust.

6. WHICH METAL WILL SACRIFICE ITSELF TO PROTECT STEEL?

   A. stainless steel
   B. platimum
   C gold
   D. aluminum

7. WHICH OF THE FOLLOWING METALS ARE SACRIFICIAL TO STEEL?

A. zinc
B. stainless steel
c. gold
D. none of the above

8. AT WHAT TEMPERATURE IS THE ALUMINUM WIRE MELTED IN THE WIRE-SPRAY GUN?

A. 2000 degrees F.
B. 300 degrees F.
c. 3000 degrees F.
D. 500 degrees F.

9. WHAT IS THE PROPER DISTANCE AND ANGLE FOR GRIT BLASTING COMPONENTS FOR PREPARATION OF WSA?

A. 5 to 6 inches at a 45 degree angle
B. 8 to 12 inches, angle does not rnatter
c. **8** to 12 inches at a 90 degree angle
D. 5 to 6 inches at a 90 degree angle

10. WHICH OF THE FOLLOWING STATEMENTS DESCRIBES THE CORRECT PROCEDURE FOR APPLYING WSA?

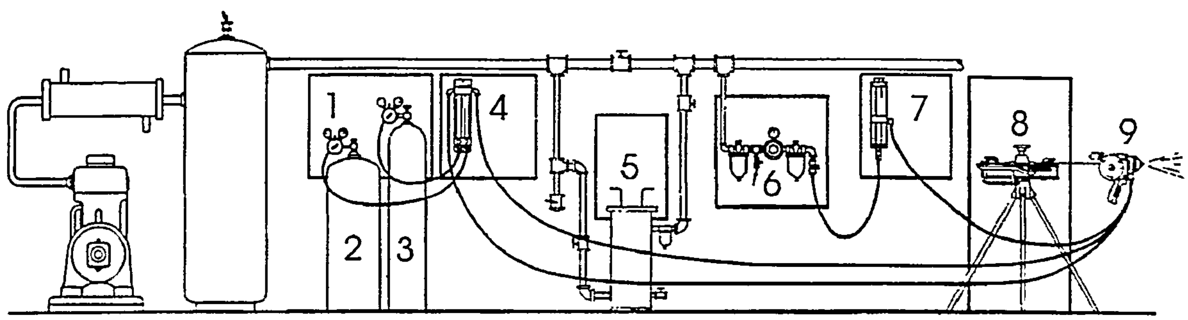
A. spray the coating at least 8 inches from the surface at a 90 degree angle.
B. spray the coating 10 to 12 inches from the surface at a 45 degree angle.
c. spray the coating 5 to 8 inches from the surface

11. WHICH OF THE FOLLOWING SAFETY DEVICES OF THE GRIT BLASTING EQUIPMENT PROVIDES FOR SECURING THE EQUIPMENT QUICKLY?

A. dead man lever
B. air pressure mechanism
c. dead man nozzle
D. shut down solenoid

GENERAL QUESTIONS

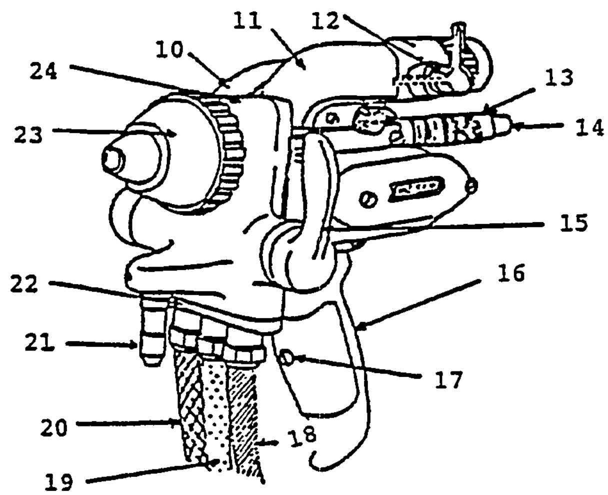
Identify each unit of the WSA installation by writing the correct identifying letter in the blank space provided next to the component number. 1 POINT PER ANSWER.



The following list defines the equipment of a typical combustion wire system.

1. ______	a. Wire Control Unit
2. ______	b. Gas Glow Meter
3. ______	c. Air Cap
4. ______	d. O-Rings
5. ______	e. Acetylene
6. ______	f. Air Flow Meter
7. ______	g. Gas Control Unit
8. ______	h. Modular
9. ______	i. Combustion Wire Gun
	j. Air receiver
	k. Air Control Unit
	l. Line Pressure for Acetylene
	m. Pyro-Psycrometer
	n. Oxygen
	o. Air Compressor
	p. Dew Point Regulator
	q. Air Cleaner
	r. Air Cap Equivalency Meter
	s. Annular Gauge Bottle
	t. After Cooler

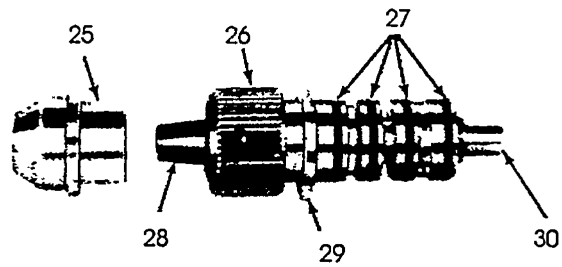
WSA GUN NOMENCLATURE - Identify each item that is part of the gun. Write the correct letter that identifies the part in the corresponding numbered spaces. 1 POINT PER ANSWER.



This list defines the components of a combustion wire gun.

10. _______	a. Gun Handle
11. _______	b. Air Cap Body
12. _______	c. Wire Input
13. _______	d. Gas Head
14. _______	e. Gun Handle Screw
15. _______	f. Tool Post Fixture
16. _______	g. Air Hose Connector
17. _______	h. Speed Control
18. _______	i. Drive Roll Carrier
19. _______	j. Hose Connection Block
20. _______	k. Wire Snubber Assembly
21. _______	l. Acetylene Connector
22. _______	m. Valve Handle Assembly
23. _______	n. Oxygen Hose Connector
24. _______	o. Wire Grip Mechanism

IDENTIFY EACH ITEM THAT IS PART OF THE GUN. Write the correct letter that identifies the part in the corresponding numbered space.



_______ 25.

_______ 26.

_______ 27.

_______ 28.

_______ 29.

_______ 30.

a. Valve Core
b. Air Cap
c. Gas Head
d. Valve Screw
e. Nozzle
f. Hose Connection
g. Nozzle Retainer Nut
h. O-Rings
i. Mounting Stud
j. Siphon Plug
k. Plunger Spring
l. Wire Guide

LIST THE PARAMETERS FOR THE GUN COMMONLY USED IN YOUR SHOP WITH ACETYLENE FUEL GAS, SPRAYING 1/8 INCH ALUMINUM WIRE.

31.	32.	33.	34.	35.	36.	37.	38.	39.
AIR CAP	LIGHTING PRESSURE			FLOWMETER READINGS			GUN DISTANCE	NOZZLE
	OXY	ACTY	AIR	OXY	ACTY	AIR		

GENERAL QUESTIONS

2 POINTS PER ANSWER.

40. WHAT IS THE OPTIMUM COATING THICKNESS RANGE OF FLAME SPRAYED ALUMINUM APPLIED FOR THE PURPOSE OF CORROSION CONTROL?

High Temp - ______________________________

____

Normal - ______________________________

____

41. WHAT PROCEDURE IS TAKEN IF COATING THICKNESS IS GREATER THAN 0.020"?

____

____

____

____

42. WHAT PROCEDURE IS TAKE IF COATING THICKNESS IS BELOW ACCEPTABLE THICKNESS? ______________________________

____

____

____

43. COATINGS THAT ARE THICKER THAN 0.020" WILL DISBOND AND PEEL IN SERVICE BECAUSE OF INTERNAL STRESSES DEVELOPED DURING APPLICATIONS. WHY ARE COATINGS LESS THAN 0.007" THICK UNACCEPTABLE?

____

____

____

____

EVALUATION SHEET

OPERATOR CERTIFICATION TEST

NAME ______________________________

SERIAL # ______________________________

COMPLETION DATE ______________________________

		SATISFACTORY	UNSATISFACTORY
1.	CLASSROOM TRAINING THEORY	________	________
2.	CLASSROOM SPRAYING TECHNIQUES	________	________
3.	ON THE JOB TRAINING	________	________
4.	GUN DISASSEMBLY/REASSEMBLY	________	________
5.	SPRAYED COUPONS	________	________
6.	COUPON BEND TEST	________	________

REMARKS ____

____

____

QUALIFYING OPERATOR ______________________

QUALITY ASSURANCE SUPERVISOR ______________________

CERTIFICATION TEST RECORD PER DOD-STD 2138

OPERATOR: ______________ **DATE:** ______________

BOND TEST (COATING THICKNESS MIN. OF 0.015″)

THICKNESS	SPECIMEN	TENSILE	AVERAGE	PROFILE
______	#1	______	______	______
______	#2	______	______	______
______	#3	______	______	______
______	#4	______	______	______
______	#5	______	______	______

SHAPE TEST (COATING THICKNESS 0.010″ - 0.015″)

THICKNESS AVERAGE	SPECIMEN	PROFILE
__________	"T" BAR ____	
__________	PIPE	____

KNIFE TEST

SATISFACTORY ________ UNSATISFACTORY ________

BEND TEST (3″ X 2″ X 0.050″ /COATING THICKNESS 0.007″ - 0.010″)

THICKNESS	SPECIMEN	VISUAL	BEND	PROFILE
______	# 1	______	______	______
______	# 2	______	______	______
______	# 3	______	______	______
______	# 4	______	______	______

____

QUALITY ASSURANCE SUPERVISOR

APPENDIX E:
PROCESS DOCUMENTS

APPENDIX E

SAMPLE PROCESS DOCUMENTS

The following pages contain representative forms used to document (1) a check-off list for supplies, tools, equipment and consumables to control items issued for an on-site job, (2) production and quality control in process verifications, and (3) parameters for a Metco-type 12E combustion gun for high temperature applications. These forms have proven to be useful to maintain the required records and documentation for thermal sprayed aluminum work.

THERMAL SPRAY ON-SITE EQUIPMENT
CHECK-OFF LIST

MASKING EQUIPMENT	TYPE	SIZE	QTY OUT	QTY IN	CONSUMED
Tape _______	Fiberglass Silicon _______ Duct _______ Other _______				
Silicon Sheet	36" x 36"				
Silicon Plugs _______	Small _______ Medium _______ Large _______ Silicon Other				
Liquid Mask					
Visqueen					
Blasting Shroud Cloth					
Plywood					
High Temp Cloth					
Sheet Metal					
Solvent _______________	Type				
Rags					
Trash Bags					
Razor Blades					

BLASTING EQUIPMENT TYPE	SIZE	QTY OUT	QTY IN	CONSUMED
Blast Pot				
Recovery System				
Dust Collector				
Grit Mesh Size				
Hoses Dead Man ____ Blast ____ Vacuum ____				
Dust Collection Ducting				
Sheet Metal				
Connectors for Exhaust Ducting				
55 Gallon Drum and Lid				
Blast Nozzle Straight ____ Angle ____ Other ____				
Abrasive Blast Helmet				
Hard Hat				
Rubber Face Mask				
Cloth Head Cover				
Blasting Gloves Rubber ____ Leather ____				
Air Breather				

BLASTING EQUIPMENT Spare Parts and Consumables	SIZE	QTY OUT	QTY IN	CONSUMED
Grit Type ____ Type ____				
Blast Nozzles				
Blast Hose Connectors				
Rubber Gaskets Nozzles ____ Hoses ____				
Blast Lenses Plastic Inner ____ Mylar Outer ____ Glass ____				
Blast Gloves				
Nozzle Holder				
Screws for Holder				
Dead Man Valve Repair Kit				
Dead Man Handle				
Cover for Blast Pot				
Blast Helmet				
Spare Parts				

SPRAY EQUIPMENT	SIZE	QTY OUT	QTY IN	CONSUMED
Combustion Wire				
Gun Type				
Console				
Wire Pack				
Gun Oxygen Fuel Air Hoses				
Gages				
Oxygen Fuel				
Gas Manifolds				
Hoses (Oxygen and Fuel)				
Bottle Rack				
Gun Extension				
Angle Air Caps				
Striker				
SPARE PARTS/CONSUMABLES	**SIZE**	**QTY OUT**	**QTY IN**	**CONSUMED**
Oxygen Bottles				
Gas Bottles				
Aluminum Wire				
Nozzles				
Air Caps				
Gun Tools				
O Rings				
Valve Lube				
Gear Lube				
Q.A. EQUIPMENT	**SIZE**	**QTY OUT**	**QTY IN**	**CONSUMED**
Currently Calibrated Equipment				
Magnetic Thickness Gage				
Bend Test Fixture				
Surface Pyrometer				
Testex Profile Test Kit				
Temperature/Humidity Gage				
Dew Point Chart				
Bend Test Samples				
Press-o-film				

DOCUMENTATION	SIZE	QTY OUT	QTY IN	CONSUMED
Shop Traveler				
Specification				
Process Control Procedure (PCP)				
Inspection Forms				
SAFETY EQUIPMENT	**SIZE**	**QTY OUT**	**QTY IN**	**CONSUMED**
Hard Hats				
Safety Glasses/Side Shields				
Ear Plugs				
Blasting Leathers				
Knee Pads				
Air Breather Helmet (for spraying)				
Air Breather Filter				
Fire Extinguisher				
Safety Belts				
Safety Shoes				
Walkie-Talkies				
AIR DRYERS	**SIZE**	**QTY OUT**	**QTY IN**	**CONSUMED**
Air Hose (From Compressor)				
Air Hose (Air Dryer to Blast Pot)				
Air Hose (Air Dryer to Air Breather)				
Air Hose (Air Dryer to Vacuum)				
Air Hose (Air Dryer to Console)				
Electrical Cords (Supply to Air Dryer)				
Air Dryer (Disconnect to Arc Gun)				
Air Dryer (Supply to Exhaust Blower)				
SEALING EQUIPMENT	**SIZE**	**QTY OUT**	**QTY IN**	**CONSUMED**
Sealer ______ ______ ______				
Solvent ______ ______ ______				
Paint Gun				
Paint Brushes				
Dobbers				
Paint Filters/ Strainers				
Mixers				

MISCELLANEOUS EQUIPMENT	SIZE	QTY OUT	QTY IN	CONSUMED
Portable Lights				
Extension Cords				
Pipe and Fitting Kit				
Ladder				
Stand				
MISCELLANEOUS TOOLS	**SIZE**	**QTY OUT**	**QTY IN**	**CONSUMED**
Pipe Wrench ______ ______ ______				
Crescent Pipe ______ ______ ______				
Oper-End Pipe ______ ______				
Wire Cutters				
Small Gage Wire				
Screw Drivers Small ______ Standard Med ______ Phillips Large ______				
Striker / Spare Flint				
Pliers Standard ______ Needle Nose ______ Linesman ______				
Channel Lock Small ______ Med ______ Large ______				
Hammer				
Nails				
Screw Kit				
Nuts / Bolts Kit				
Pry Bar Small ______ Med ______				
Portable Drill				
Portable Screw Gun				
Hack Saw (Extra Blades)				
Power Saw ______ ______				
Hose Clamps ______ ______ ______				

NATIONAL STEEL AND SHIPBUILDING COMPANY

WIRE SPRAY ALUMINUM
MATERIAL TRAVELER/CHECKPOINT DATA

RECEIPT

Enter "N/A" in all blanks not applicable to the items being processed.

Date: ____________________

P.O. / W.O. # ____________________ Part Name: ____________________

Serial # ____________________ Quantity: ____________________

PERSONNEL

Blast Equip. Operators	Flame-Spray Operators	Inspectors
________	________	________
________	________	________

MATERIAL PREPARATION

	TASK				ANCHOR-TOOTH READINGS	
	SOLVENT CLEAN	MASK	STRIP BLAST	FINAL BLAST		
					____	____
Operator's Initials -	____	____	____	____	____	____
Time	____	____	____	____	____	____

WSA PROCESS CHECK

	Sample Coupon Test Results				
	#1 ____	#2 ____	#3 ____	#4 ____	#5 ____
Inspector's Initials - - -	____	____	____	____	____

WSA APPLICATION

Ambient Temperature ________ ° F Relative Humidity ________ %

Preheat Temperature ________ °F Time ________ Inspector ____________________

Thickness Readings ________ ________ ________ ________ ________

SEAL COAT APPLICATION

Elapsed time since WSA application ________ hrs. Initials ________

Steel Temp. ________ ° F Ambient Temperature ________ ° F Relative Humidity ________ %

Thickness Readings ________ ________ ________ ________ ________

SUBSEQUENT COATING APPLICATION

Coating Type: ____________________ Batch/Lot #: ____________________

Steel Temp. ________ ° F Ambient Temperature ________ ° F Relative Humidity ________ %

Coat #-------------		1	2	3	Average
Dry Film Thickness (DFT)	1	____	____	____	____
	2	____	____	____	____
	3	____	____	____	____
	4	____	____	____	____
	5	____	____	____	____
Average		____	____	____	____

Application and inspection of the coatings, as described herein, was performed as required by the NASSCO Flame Spray Manual.

Inspector ____________________ Date ____________________ **RESULTS:** Satisfactory ____ Unsatisfactory ____

QUALITY ASSURANCE REPORT

CUSTOMER: ______________________ DATE: ______________________

PURCHASE ORDER NO.: ______________________ CONTROL NO.: ______________________

PART NAME: ______________________ QUANTITY: ______________________

PART NO.: ______________________ PART MATERIAL: ______________________

SERIAL NO.: ______________________ REFERENCE SPEC.: ______________________

MATERIAL SPRAYED: ____________ ____________ ____________

MATERIAL LOT NO.: ____________ ____________ ____________

INSIDE & OUTSIDE SHOP TRAVELER

DESCRIPTION OF WORK: ____

______________________________________ ITEM NO.: ______________

	OPERATOR	Q.A. INITIALS	TIME
PREPARATION/MASKING	________		
	________	________	________
STRIP BLAST	________		
	________		
START ANCHOR TOOTH	________	________	________
PROFILE CHECK ______ avg. (Put Presso Film Sample on the back of this page)		________	

REPRESENTATIVE BEND & TEST COUPONS
(Mark coupons with Control No. and Sample No.)

ACCEPT	REJECT	SAMPLE #	OPERATOR	Q.A. INITIALS	TIME
______	______	______	________	________	________
______	______	______	________	________	________
______	______	______	________	________	________
______	______	______	________	________	________

WSA THICKNESS CHECK
Average Thickness

	OPERATOR	Q.A. INITIALS	TIME
________			
________			
________		________	________
SEALING	________	________	________

NOTES: ____

____

____

NATIONAL STEEL AND SHIPBUILDING COMPANY

P.O. Box 85278
Harbor Drive and 28th Street
San Diego, California 92138

FLAME SPRAY PROCEDURE # FSP 5.1-2

CATEGORY I
HIGH TEMPERATURE APPLICATION

The parameters contained herein, in conjunction with all the applicable requirements of the NASSCO Flame Spray Manual, has been developed in accordance with Dod-STD-2138, and will be adhered to by the qualified flame spray operators applying Wire-Spray Aluminum for the corrosion control of equipment and material aboard U.S. Navy vessels.

Base Material Steel

Spray Material: Aluminum Wire

Specification: Mil-W-6712

Material Preparation

Solvent Clean

Mask: Machined surfaces and/or 1½" from weld edge prep.

Blast Specification: SSPC SP-5 "White Metal"

Media: Aluminum Oxide @ 20 Grit @ 2 to 3 mils profile

Nozzle: Size 3/16" — Nozzle to Work Distance @ 6"

Equipment (Spray)

Spray Gun: Metco 12E — Nozzle Orifice Size 1/8"

Type Gears: Standard — Air Cap EC

Gases

Pressures (psig)		Acetylene	Oxygen	Air
	Lighting	15	35	N/A
	Flow	40	43	52

Coating Parameters

		Pass	Total
Pounds/Hour	12	Thickness 3 to 4 mils	10 to 15 mils

Preheat Temp. 150 to 200° F — Gun to Work Distance 5" to 8"

Remarks:
For seal coating see paragraph 5.6 of this manual. Indicate procedure number, preprocess test results and the coating category on the Traveler/Checkpoint Data Report.

APPENDIX F:
FACILITY PLANS

APPENDIX F

FACILITY LAYOUT PLANS

Figure F-1 shows the floor plan of NASSCO'S containerized blast and thermal spray facility installed in 1988 to support the Navy's AOE program. In lieu of constructing a building or finding an existing building to house the thermal spray facility, NASSCO elected to purchase modular containerized systems and set them in place on an existing slab. Although these units in all likelihood will never be moved, they could be easily relocated. For the level of effort on the AOE, this system has proven to be adequate to process the required components.

Figure F-2 shows the arrangement of NASSCO'S portable thermal spray skid. This unit is essentially a large tool box and central work center for on-block or on-board work. It neatly houses all the thermal spray equipment necessary to accomplish coatings in remote areas. This skid, in conjunction with a newly designed abrasive blast / recovery and dust collection skid, provides NASSCO with the ability to perform on-site work effectively.

Figure F-3 presents the design for an "ideal" thermal spray facility. This floor plan illustrates a proposed high production facility. It includes all necessary cleaning, blasting, thermal spraying, painting and powder coating equipment. The flow and handling of components is through a precleaning and masking area, strip blasting, anchor-tooth blasting, thermal spray coating application or powder coating stations. This design optimizes the handling and production flow of components.

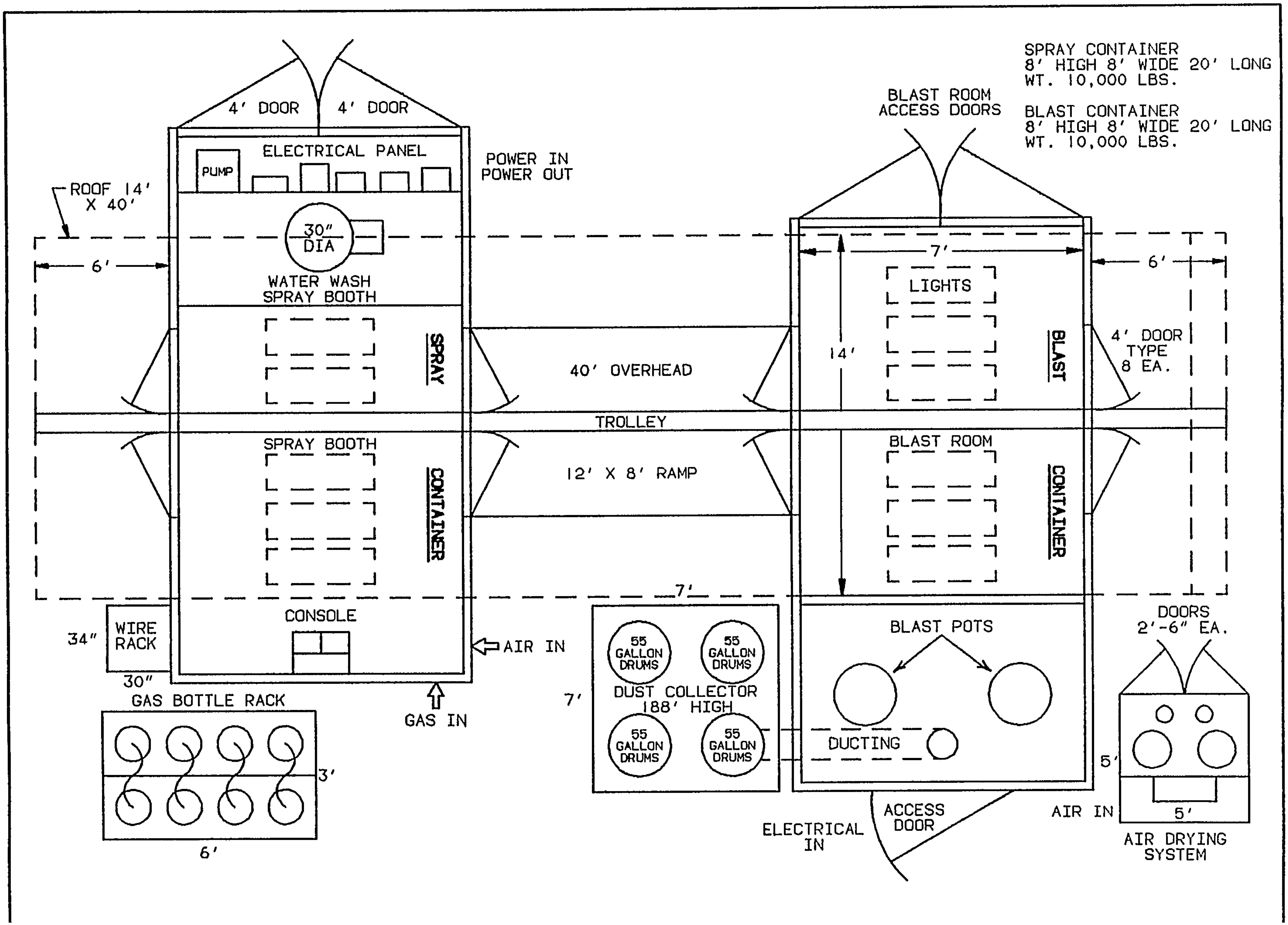


Fig. F-1. Floor Plan of NASSCO's Containerized Thermal Spray System

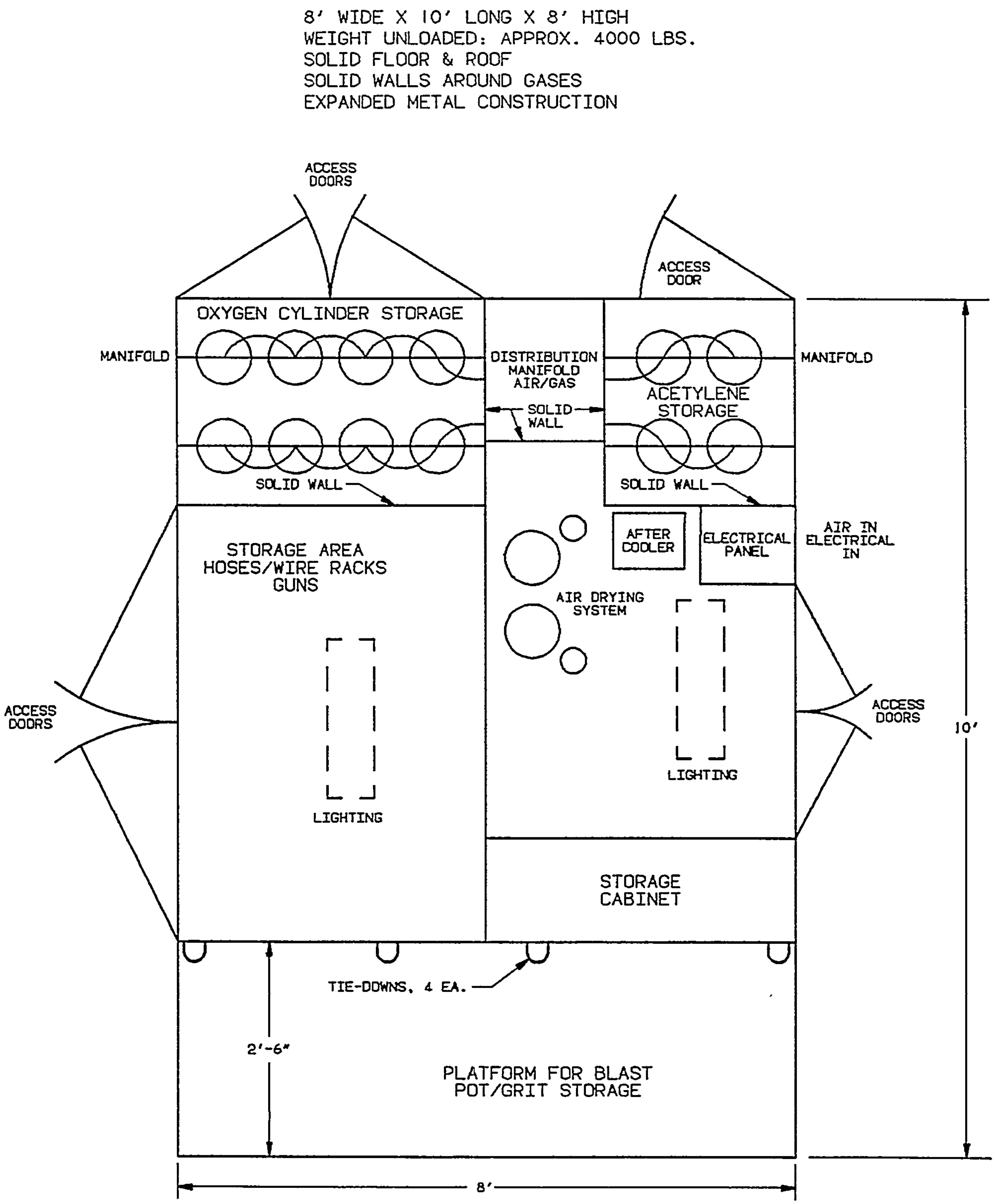


Fig. F-2. Portable Thermal Spray Skid

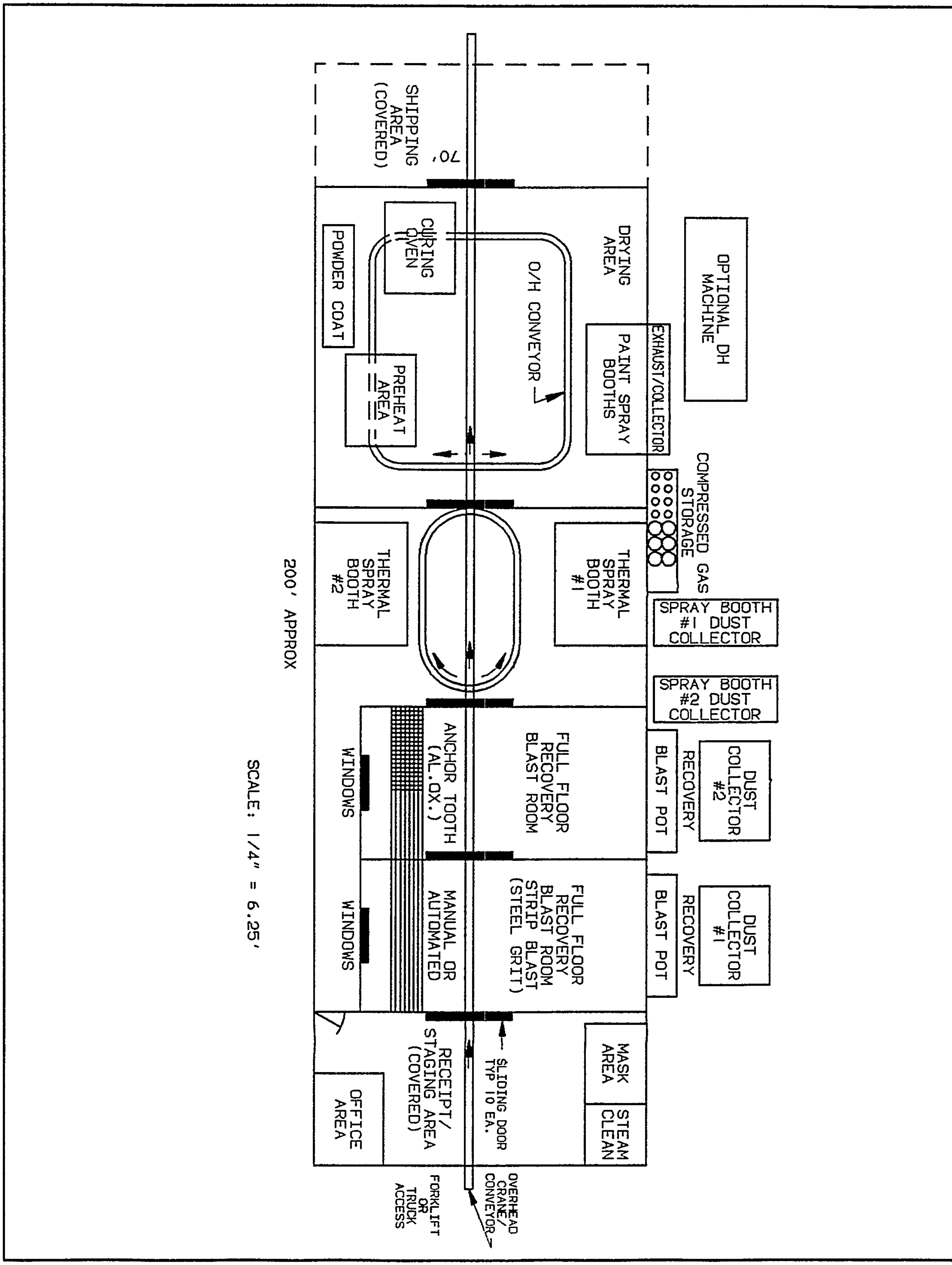


Fig. F-3. Proposed "Ideal" Thermal Spray Facility Floor Plan

APPENDIX G:
TABLES AND CHARTS

APPENDIX G

INFORMATIONAL TABLES AND CHARTS

The following pages contain tables and charts to provide information that can be used on a daily basis to support a thermal spray facility.

DESCRIPTION OF CHARTS AND TABLES

1. WEIGHTS OF ALUMINUM WIRE IN POUNDS PER FOOT AND NUMBER OF FEET PER POUND. POUNDS OF ALUMINUM / HOUR CONVERTED TO FEET / MNUTE.

   These charts will quickly enable the user to determine if the appropriate pounds per hour of wire is being sprayed through a metalizing gun.

2. DECIMAL AND FRACTION CONVERSION TABLE.
   1/64 to 63/64 Conversion table.

3. TEMPERATURE CONVERSION CHART.
   Degrees F. to Degree C.

4. GEOMETRY FORMULAS.
   These basic formulas are most commonly used to determine the area of a component to be TSA processed.

5. DEW POINT CHART.
   During TSA processing it is necessary to know the dew point. This chart enables the user to determine the dew point once the temperature and relative humidity are obtained.

6. COMPARISON OF THERMAL SPRAY GUNS.
   This table lists the basic thermal spray gun types, and compares their spray rates, deposit efficiencies and spray distances.

7. GRIT CONTAMINANT AND SIZE VERIFICATION PROCEDURE.
   Each day the quality of the grit must be checked for both size and contamination. This procedure is a simple, reliable method of checking the grit quality.

WEIGHTS OF ALUMINUM WIRE

WIRE SIZE	DIAMETER	WEIGHT POUNDS PER FEET	NUMBER FEET PER LB.
3/16"	0.1875	0.03173	31.52
1/8"	0.125	0.0141	70.92
11 ga.	0.091	0.0075	133.33
15 ga.	0.0571	0.0029	344.82

SPRAYING SPEED CONVERSION TABLE
Pounds per Hours - Feet per Minute

Wire Size	FEET PER MINUTE														
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
	POUNDS PER HOUR														
3/18"	1.91	3.81	5.71	7.61	9.52	11.42	13.32	15.23	17.14	19.05	22.92	26.74			
1/8"	.85	1.69	2.54	3.38	4.23	5.08	5.92	6.77	7.61	8.46	10.20	11.90			
11 ga.	.45	.90	1.35	1.80	2.25	2.70	3.15	3.60	4.05	4.50	5.40	6.30			
15 ga.	.17	.35	.52	.70	.87	1.04	1.22	1.39	1.57	1.74	2.09	2.44	2.78	3.06	3.40

FRACTION / DECIMAL CONVERSION TABLE

FRACTION	DECIMAL	FRACTION	DECIMAL
1/64	.015625	**5/16**	**.3125**
1/32	.03125	21/64	.328125
3/64	.046875	11/32	.34375
1/16	**.0625**	23/64	.3359375
5/64	.078125	**3/8**	**.375**
3/32	.09375	25/64	.390625
7/64	.109375	13/32	.40625
1/8	**.125**	27/64	.421875
9/64	.140625	**7/16**	**.4375**
5/32	.15625	29/64	.453125
11/64	.171875	15/32	.46875
3/16	**.1875**	31/64	.484375
13/64	.203125	**1/2**	**.50**
7/32	.21875	33/64	.515625
15/64	.234375	17/32	.53125
1/4	**.250**	35/64	.546875
17/64	.265625	**9/16**	**.5625**
9/32	.28125	37/64	.578125
19/64	.29687	19/32	.59375

FRACTION / DECIMAL CONVERSION TABLE (cont'd.)

FRACTION	DECIMAL
39/64	.609375
5/8	**.625**
41/64	.640625
21/32	.65625
43/64	.671875
11/16	**.6875**
45/64	.703125
23/32	.71875
47/64	.734375
3/4	**.750**
49/64	.765625
25/32	.78125
51/64	.796875

FRACTION	DECIMAL
13/16	**.8125**
53/64	.828125
27/32	.84375
55/64	.859375
7/8	**.875**
57/64	.8890625
29/32	.90625
59/64	.921875
15/16	**.9375**
61/64	.953125
31/32	.96875
63/64	.984375

FAHRENHEIT TO CENTIGRADE CONVERSION

FAHRENHEIT (F.)	CENTIGRADE (C.)
350 Degrees F.	176 Degrees C.
325 Degrees F.	162 Degrees C.
300 Degrees F.	148 Degrees C.
250 Degrees F.	121 Degrees C.
212 Degrees F.	100 Degrees C.
150 Degrees F.	65 Degrees C.
125 Degrees F.	51 Degrees C.
100 Degrees F.	38 Degrees C.
75 Degrees F.	24 Degrees C.

METRIC CONVERSION

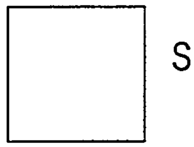
1 Millimeter (mm) = 0.03937 Inches
1 Inch = 2.54 centimeters (cm) = 25.4 mm
1 Meter (m) = 3.28 Feet
1 Foot = 30.5 cm

GEOMETRY

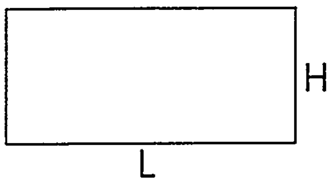
π = 3.14159
Cir. = Circumference
Dia. = Diameter
A = Area
R = Radius

Cu. In. = cubic inches
Sq. Ft. = square feet
Cu. Ft. = cubic feet
Sq. In. = square inches
144 Sq. In. = 1 square foot

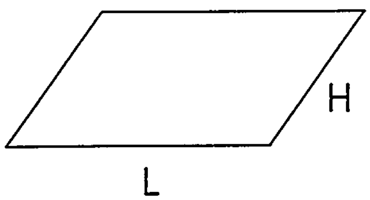
GEOMETRY AREA FORMULAS



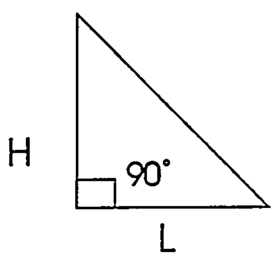
Square Area = S^2



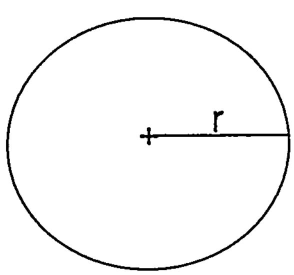
Rectangle Area = L x H



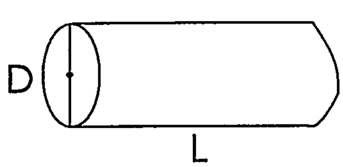
Parallelegram Area = L x H



Right Angle Triangle Area = (½) L x H



Circle Area = Πr^2



Cylinder Area = D x Π x L

DEW POINT CHART

TEMPERATURE (F)	RELATIVE HUMIDITY (%)	DEW POINT (F)	TEMPERATURE (F)	RELATIVE HUMIDITY (%)	DEW POINT (F)
50	50 60 70 80 90	42.0 43.8 45.2 47.0 48.8	70	50 60 70 80 90	58.6 61.0 63.5 65.6 68.0
55	50 60 70 80 90	46.1 48.0 49.9 51.6 53.4	75	50 60 70 80 90	62.5 65.3 68.0 70.5 72.8
60	50 60 70 80 90	50.1 52.5 54.0 56.2 58.0	80	50 60 70 80 90	65.0 68.0 70.8 73.2 75.6
65	50 60 70 80 90	54.2 56.7 59.0 61.0 63.1	85	50 60 70 80 90	66.8 69.9 72.6 75.0 77.8

GUN CHARACTERISTIC COMPARISON

CHARACTERISTIC	WIRE GUN	POWDER GUN	ARC GUN
Spray Rate	12 lb/hr	12-15 lb/hr	12-20 lb/hr
Deposit Efficiency	90 %	90-95%	70%
Spray Standoff Distance	5-7 Inch	5-7 Inches	6-8 Inches
Spray Angle	90 $\pm$ 45 degrees to substrate		
Crossing Passes	Minimum of 2 (to avoid holidays and thin areas)		
Spray Width	½" (Normal air cap) 2" (Fan spray air cap)	½" (Normal air cap)	½-2" (Fine air cap) 2-6" (Wide air cap)
Pounds Aluminum Required/Cu. In.	0.10	0.10	0.10

PROCEDURE TO DETERMINE THE OIL CONTAMINATION OF ABRASIVE BLASTING GRIT

1. Place 400 mls. of grit in an 800 ml. container.
2. Add water to the grit up to approximately the 700 ml. mark
3. Stir the water and grit for approximately 30 seconds.
4. Cover container and let stand still for 12 hours.
5. After 12 hours and before disturbing the container, visually check to see if there is any oil floating on top of the water.
6. If there is any oil visible, discard the grit and check source of oil contamination before recharging the Abrasive Blast System:

PROCEDURE FOR DETERMINING EXCESSIVE FINES IN ABRASIVE BLASTING GRIT

Grit shall not exceed 20% by weight when compared with new grit, or contain visual foreign contaminants.

1. Place 50 mls. of new grit in a 100 ml. container.
2. Weigh the container to establish its weight with new grit (key).

   Key: #24 grit -50 nils. = .345 lbs. (new grit)

3. Place 50 mls. of used grit in the same 100 ml. container.
4. Weigh the container, then use the example fornuda below.

   Used grit (example = .365 lbs.)

   .345 lbs. (new grit) ÷ .365 lbs. (used grit) = .94
   which = 6% fines

5. Visually inspect grit for foreign materials such as paint, scale, rust, etc.
6. Should the fines measure in excess of 20%, discard or re-screen the grit prior to use for preparation of thermal sprayed coating applications.

APPENDIX H:
DOD-STD-2138(SH)

APPENDIX H

DoD STANDARD 2138 (SH)

NOTE:

A revision to this Standard is expected to be issued by mid-1992. Copies may be obtained by using the order form included on page 34 of this Standard.

METRIC

DOD-STD-2138(SH)
23 November 1981

MILITARY STANDARD

METAL SPRAYED COATING SYSTEMS FOR CORROSION PROTECTION ABOARD NAVAL SHIPS

(METRIC)

NO DELIVERABLE DATA REQUIRED
BY THIS DOCUMENT

AREA MFFP

(134)

DEPARTMENT OF DEFENSE

Washington, DC 20362

Metal Sprayed Coating Systems for
Corrosion Protection Aboard
Naval Ships

DOD-STD-2138 (SH)

1. This Military Standard is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 3112, Department of the Navy, Washington, DC 20362 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 -. This standard covers the requirements for the use of metal sprayed coatings (aluminum and zinc) for corrosion-control applications aboard Naval surface ships. The requirements specified by this standard are applicable to wire-flame spraying of consumable coating material using oxygen-fuel gas, restricted use of electric arc spray, and powder metal spraying using oxygen-fuel gas for selected corrosion-control applications. This standard covers: certification of facilities, certification of operators, application procedures, metal-spray procedures, production quality assurance, test procedures, and records.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

O-T-620 -1,1,1 -Trichloroethane, Technical Inhibited (Methyl Chloroform).
BB-A-106 - Acetylene, Technical, Dissolved.
BB-O-925 - Oxygen, Technical, Gas and Liquid.
lT-T-548 - Toluene, Technical.

MILITARY

MIL-M-3800 - Metallizing Outfits (Wire Gas), Guns and Accessories.
MIL-W-6712 - Wire; Metallizing.
MIL-P-23377 - Primer Coatings: Epoxy-Polyamide, Chemical and Solvent Resistant.
MIL-P-24441 - Paint, Epoxy-Polyamide, General Specification for.
MIL-P-24441/l - Paint, Epoxy-Polyamide, Green Primer, Formula 150.
MIL-P-24441/2 - Paint, Epoxy-Polyamide, Exterior Topcoat, Haze Gray, Formula 151.
DOD-P-24555 - Paint, Aluminum, Heat-Resisting (650 C), Low-Emissivity (0.40 or Less) (Metric).
MIL-M-80141 - Metallizing Outfits, Powder-Gas, Guns and Accessories.
MIL-M-80226 - Metallizing System, Wire, Electric Arc, Guns, and Accessories.
MIL-P-83348 - Powder, Plasma Spray.

STANDARD

MILITARY

MIL-STD-l 687- Metal Spray Processes for Naval Ship Machinery and Ordnance Applications.

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND

NAVSEA S9086-VD-STM-000, Chapter 631 - Preservation of Ships in Service (Surface Preparation and Painting).

NAVSEA S9086-CH-STM-030, Chapter 074, Volume 1 - Welding and Allied Processes.

NAVSEA S9086-CH-STM-030, Chapter 074, Volume 3 - Gas Free Engineering.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other Publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) C 633 - Adhesion or Cohesive Strengths of Flame-Sprayed Coating, Test Method for.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

AMERICAN WELDING SOCIETY (AWS)

A3.O - Welding Terms and Definitions including Terms for Brazing, Soldering, Thermal Spraying, and Thermal Cutting.

C2.1 - Recommended Safe Practices for Thermal Spraying.

(Application for copies should be addressed to the American Welding Society, 2501 Northwest 7th Street, Miami, FL 33125.)

STEEL STRUCTURES PAINTING COUNCIL (SSPC)

SSPC No. 5- Volume 2, Section 2, White Metal Blast Cleaning.

(Application for copies should be addressed to the Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA 15213.)

DEPARTMENT OF LABOR

Code of Federal Regulations, Title 29 Part 1910- Occupational Safety and Health Standards.

(Applications for copies should be addressed to the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. DEFINITIONS

3.1 Thermal spraying terminology and definitions. Terminology and definitions used in the preparation of drawings, spraying procedures, specifications and correspondence related to thermal spraying shall conform to AWS A3.O.

3.2 Other definitions.

3.2.1 Acceptable. Complies with or conforms to the applicable standard or specification.

3.2.2 Approved (approval). The item under consideration has been sanctioned in writing by the Commander, Naval Sea Systems Command (NAVSEA) or his authorized agent.

3.2.3 Authorized agent. Any Government representative specifically authorized to approve equipment, materials, or procedures within the scope of this standard for NAVSEA. The authorized agent shall have appropriate training and experience to implement and evaluate inspection functions of this standard. They are as follows:

(a) For Government shipyards: The delegated representative of the Shipyard Commander.
(b) For commercial shipyards: The delegated representative of the Supervisor of Shipbuilding, Conversion and Repair.
(c) NAVSSES: Naval Ship Systems Engineering Station Philadelphia is also authorized to provide field support for Naval activities.
(d) For commercial activities other than shipyards: The delegated representative of the Defense Contract Administration Services Management Area (DCASMA).

3.2.4 Inspector. A contractor, Naval Shipyard, or Government agency employee designated to accept or reject materials or workmanship on the basis of the results of specified tests.

3.2.5 Certified. The item under consideration has been approved as required by this standard.

3.2.6 Procedure. A metal spray procedure is a written instruction which contains all the applicable essential elements listed in this document.

3.2.7 Application Procedure. The method used to apply the metal sprayed coatings for corrosion control.

3.2.8 Blasting. A method of cleaning or surface roughening by a forcibly projected stream of sharp angular abrasive.

3.2.9 Flame spraying. A metal spraying process wherein an oxygen-fuel gas flame is utilized as the source of heat for melting the coating material. Compressed air may or may not be used for atomizing and propelling the material to the work piece.

3.2.10 Electric arc spraying. A metal spraying process using an electric arc as a heat source between two consumable wires. Compressed air or inert gas is used to atomize and propel the molten material to the substrate.

3.2.11 Interface. The contact surface between the spray deposit and the substrate.

3.2.12 Masking. The method of protecting the areas adjacent to the areas to be thermal sprayed or blasted to prevent adherence of a coating or surface roughening.

3.2.13 Powder metal flame spraying. A method of metal spraying wherein the metal to be sprayed is in powder form.

3.2.14 Seal Coat. Material applied to infiltrate the pores of a metal spray deposit.

3.2.15 Spalling. The flaking or separation of a sprayed coating.

3.2.16 Substrate. Any material upon which a coating of sprayed metal is deposited.

3.2.17 Metal spraying. A group of processes wherein finely divided metallic materials are deposited in a molten or semi-molten condition to form a coating. The coating material may be in the form of powder or wire.

3.2.18 Wire flame spraying. A method of metal spraying wherein the metallic material to be sprayed is originally in wire form.

4. GENERAL REQUIREMENTS

4.1 Safety precautions (Personnel hazard). All personnel concerned with metal spraying shall become familiar with and follow the practices specified in AWS C2.1, NAVSEA S9086-CH-STM-030, Chapter 074, Volume 3, and NAVSEA S9086-VD-STM.000, Chapter 631. Safety and health requirements as specified in OSHA 29 CFR 1910 shall also be followed.

4.1.1 Cleaning solvents (toluene or trichloroethane). Shipping containers are marked to indicate dangerous or safety related items. These labels shall be read prior to using the solvent and the stated precautions followed in their use. The following safety precautions shall be followed when using toluene and trichloroethane:

(a) Toluene vapor is flammable - keep away from heat, sparks, and open flame.
(b) Toluene and trichloroethane vapors are harmful and can be fatal - use only in adequate ventilation. Avoid prolonged breathing of vapor.
(c) Avoid prolonged or repeated contact with skin.

4.1.2 Metal spray gases. NAVSEA S9086-CH-STM-030, Chapter 074, Volume 3 shall be used for guidance and the following safety precautions followed when using metal spray gases:

(a) Inspect all gas equipment regularly for leaks and loose connections.
(b) Charged gas cylinders are potentially dangerous. Keep cylinders away from heat. Always secure cylinders to keep them from toppling. Shut off gas and place valve caps on the cylinders when they are not is use.
(c) Do not hang a metal spray gun on a regulator or cylinder valve. Provide for portable equipment storage or permanent work station.
(d) Provide adequate ventilation of the work area before opening any of the gas valves. No container shall be presumed to be clean or safe until proven and certified safe by a Gas Free Engineer.
(e) Never point a gas hose, air hose, or other pressurized item at any part of the human body, your own or others.

4.1.3 Blast cleaning. Safety precautions for abrasive blasting specified below and covered by NAVSEA S9086-VD-STM-000, Chapter 631 shall be followed.

(a) If fire or explosion hazards are present, precautions shall be taken before any blast cleaning is initiated. If the structure previously contained flammable materials, it shall be purged of dangerous concentrations. Prior to commencing work, structure shall be certified safe by a Gas Free Engineer.
(b) While blasting, face shields with dust hoods or helmets with forced fed purified air shall be used to protect the eyes, face, chin, and neck from airborne particles.
(c) Safety glasses or goggles shall be worn by all persons near any blasting operation.
(d) Blast hose shall be grounded to dissipate static charges.
(e) Never point a blast nozzle at any part of the human body, your own *or* others.

4.1.4 Wire spray gun. Safety precautions for wire spray guns are as follows:

(a) Wire spray guns shall be maintained in accordance with the manufacturer's recommendations.
(b) Do not light the gun without having the wire in the nozzle. Without the wire in the gun, the flame can shoot back through the front wire guide, damaging the nozzle, guide, drive rolls, and causing injury to the operator.
(c) Do not use matches for lighting wire spray guns because hand burns may result. Use a friction lighter, a pilot light, or arc ignition.

4.1.5 Reduction of respiratory hazards. The following safety precautions shall be followed in order to reduce respiratory hazards:

(a) Use of a wet spray booth with a positive exhaust system shall be used on board Navy ships and other closed areas to avoid the toxic or irritating effects of dust, fumes, and mists generated by metal spraying. Work stations shall have adequate air flow and safe breathing apparatus (see 5.2.1) in accordance with NAVSEA S9086-VD-STM-OO0, Chapter 631 and AWS C2.1 .

(b) Breathing zinc or aluminum dust may damage the respiratory system. if signs of operator discomfort develop, (i.e., dizziness or nausea), stop spraying at once and determine if the ventilating and exhaust systems are working properly before resuming the spraying operation.

4.1.6 Personal Protection. The following safety precautions shall be followed for personal protection:

(a) Never permit spray dust to enter the eyes, mouth, cuts, scratches, or open wounds. After spraying, and especially before eating or handling food, wash hands thoroughly.

(b) Finely divided metallic airborne particles can be hazardous from an explosive standpoint and partially wet metal dust creates a hazard of spontaneous combustion. For spraying in enclosed or internal spaces, see 4.4.5, category Ill.

4.1.7 Protective clothing. Flame-resistant clothing shall be used and leather or rubber gauntlets shall be worn. Clothing shall be strapped tightly around the wrists and ankles to keep dusts from harmful metal sprayed materials and abrasives away from the skin.

4.1.8 Reduction of noise hazard. Hearing protectors or properly fitted soft rubber ear plugs shall be used. Wads of cotton for hearing protection shall not be used since they do not protect against high intensity noise.

4.1.9 Eye and respirator Protection. Eye and respiratory protection shall be as follows:

(a) Helmets, face shields, or goggles shall be used to protect the eyes during all metal spraying or blasting operations. it may be necessary for metal sprayers or blasters to use goggles at all times for protection against radiation or airborne particles from adjacent operations. Attendants or helpers shall be provided with proper eye protection.

(b) While metal spraying, the helmet, face shield, or goggles shall be equipped with a suitable filter plate as required by NAVSEA S9086-CH-STM-030, Chapter 074, Volume 1 to protect the eyes from excessive infrared (as well as intense visible light) radiation. The following is a guide for the selection of the proper shade number

(1) Wire flame spraying - Shades 2-4

(2) Metal spraying of powder - Shades 3-6

(c) When metal spraying in the open, or where ventilation is adequate to eliminate the need for additional respiratory protection, properly shaded goggles only shall be worrn. These shall be of the eyecup type, fitted with

lenses of about 50 millimeters (mm) in diameter, or the coverup type for those wearing corrective spectacles.

(d) The goggles shall have indirect ventilating fins to eliminate the danger from airborne particles and to reduce fogging.

(e) While blasting, face shields or abrasive blasting helmets equipped with dust hoods shall be used to protect the eyes, face, chin, and neck from airborne particles.

4.1.10 Compressed air. The following safety precautions shall be followed when using compressed air:

(a) Compressed air shall not be used to clean clothing.

(b) Compressed air for metal spraying or blasting operations shall be used at pressures recommended by the equipment manufacturers.

(c) Compressed air shall be clean and free of oil, moisture, and other contamination for blasting and metal spraying.

4.2 Equipment.

4.2.1 Abrasive blasting system.

4.2.1.1 Blasting eqwuipment. There are three types of blasting equipment that may be used depending on the application, and as specified (see 6.4):

(a) Type I - Pressure blasting machines (blast generators).
(b) Type II - Suction blast cabinets and portable units.
(c) Type Ill - Centrifugal blast equipment.

4.2.1.1.1 Type I shall be used for large area work where the blasting is done by hand. Type I shall also be used for production jobs. The nozzles may be set in any desired position. Open blast and recirculating chamber equipment are examples of type I systems.

4.2.1.1.2 Type II is less efficient than type I but may be used for small odd lot and production work that can be handled in cabinets or portable units.

4.2.1.1.3 Type Ill is highly efficient for blasting large volume production work. The grit is thrown out in a fan from a large rotating wheel. For this reason the work shall be brought in front of the wheel or wheels and rotated so as to blast all sides. Type Ill is only practical for a limited class of work. Additional information can be obtained from NAVSEA S9086-VD-STM-000, Chapter 631.

4.2.1.2 Air equipment. The air equipment used in the abrasive blasting process shall furnish air which is free of oil and moisture (less that 0.03 parts per million (p/m) oil). The air supply shall be adequate to maintain a minimum pressure of 520 kilopascals (kPa) (75 pounds per square inch (lb/in^2) at the blast generator for angular chilled iron grit and a minimum of 350 kPa (50 lb/in^2) at the blast generator for aluminum oxide grit.

4.2.2. Spraying system {see 6.4}.

4.2.2.1 Wire oxygen-fuel gas spray system. A wire-feed metal spray system shall consist of a source of compressed air, air drying unit, air receiver, gas control unit, oxygen, fuel gas, a reel to hold the feed wire, gages and valves to control air flow, gas mixture and flow, and the spray gun itself. A typical metal spray system is shown in figure 1. A typical metal spray gun is shown in figure 2. The metallizing outfits shall meet the requirements for either class 8 or 10 of MIL-M-3800, except class 10 shall be for use with 0.8 through 5.0 mm (0.032 through 3/16 inch) diameter wire having a melting point up to and including 2600°C (4700° F). The guns shall be equipped with an air turbine or an air motor wire drive mechanism and shall have a performance capability equal to or in excess of the spraying rate requirements specified in MIL-M-3800. The class 10 gun shall also conform to all other requirements applicable to the class 8 gun as specified herein.

4.2.2.2 Air equipment. The air equipment used in the metal spraying system shall furnish air which is free of oil and moisture (less than 0.03 p/m oil). For the metallizing operation, a pressure of at least 415 kPa (60 lb/in^2) shall be available at the air control unit. There shall be not more than 11 meters (m) (35 feet) of 10 mm (3/8 inch) inside diameter (i.d.) hose between the air control unit and the wire spray gun. Each metal spray outfit shall consist of all components and accessories listed in table L

TABLE L Equipment and quantity.

EQUIPMENT	QUANTITY	
	CLASS 8	CLASS 10
Metalizing gun, complete with lubricants, carry case, tool set, and manuals	1	1
Air caps	2	4
Wire nozzles	2	4
Hose set, complete	1	1
Regulator, oxygen	1	1
Regulator, fuel gas	1	1
Flowmeter, oxygen	1	1
Flowmeter, fuel gas	1	1
Flowmeter, air	1	1
Control unit	1	1
Wire reel and stand	1	1
Wire straightener	-	1
Gun mounting fixture	1	1

4.2.2.3 Air quality. In-1ine water and oil filters shall be located between the compressor and the metal spray equipment. These filters shall be periodically inspected and serviced to assure delivery of uncontaminated dry air. When greater control is required, automatic dew point measuring instruments with feedback to control the quality of air shall be installed. Optional equipment may be required as specified in the contract for special applications in accordance with MIL-M-3800.

4.2.2.4 Powder metal spray. The powder metal spray system shall consist of powder spray gun, hoses, flowmeters, fuel gas and oxygen regulators, and mechanical or aspirator feed for powder. Equipment shall meet the requirements of MIL-M-80141, type 1, class 1.

4.2.2.5 Consumable electrode, electric arc .spray. The electric arc system shall consist of an electric arc gun, flowmeter, compressed air, air cleaner, air dryer with ceramic cartridge for intermittent work (less than 4 hours per day), or refrigerated air dryer for production work direct current (d.c.) power supply unit, dual wire feeding mechanism, controls, and all necessary connecting cables and hoses. Equipment shall meet the requirements of MIL-M-80226.

4.3 Materials.

4.3.1 Cleaning solvents. The following cleaning solvents may be used:

Solvent	Specification
Trichloroethane	O-T-620
Toluene	IT-T-548

WARNING: Toluene is flammable. Both toluene and trichloroethane are toxic. Use only in well ventilated spaces. Do not use near open flames, blasting, metal spraying work, or sources of sparks. Do not allow prolonged contact with bare skin. Read and follow precautions on container shipping labels before using contents.

4.3.2 Masking materials. Any masking material that provides adequate protection of the substrate without causing substrate corrosion or contamination may be used. Acceptable masking materials may be masking tape to protect exposed threads, gasket seats, and similar surfaces. Navy high pressure tape, NAVSEA-approved metallic tape (heat reflecting), or silicon rubber tape shall be used for delicate or critical surfaces. Plastic cap-plugs or rubber stoppers may be used for small holes or openings. Hose sections may be used to cover threaded studs, stems, and protrusions. For masking irregular shapes such as holes, slots, keyways, or other types of recesses and machined surfaces that cannot be protected with tapes or shields, inserts of wood, metal, or other form-fitting filler may be used.

4.3.3 Abrasive blasting particles. Abrasive blasting particles used to provide the anchor tooth of 50 to 75 micrometers (µm) (2 to 3 mils) during final surface preparation of the substrate shall be one of the following as specified (see 6.4):

Type abrasive	Mesh size	Surface to be blasted
Aluminum oxide grit	16-30	Steel or aluminum
Angular chilled iron grit	25-40	Steel

4.3.3.1 Requirements. Abrasive particles shall be clean, dry, sharp, and free of rust and excessive fines. Excessive fines are defined as greater than 25 percent fines.

4,3.3.2 Restrictions. Abrasive particles shall not contain any feldspar or other mineral constituents that tend to breakdown and remain on the surface. Abrasive particles that have been used for cleaning heavily contaminated surfaces shall not be used for final surface preparation, even though the abrasive has been rescreened. iron grit shall not be reused for anchor tooth blasting. Angular chilled iron grit shall not be used for blasting of aluminum or other materials when contamination of the surface may result from the presence of iron residue. Use of iron grit on aluminum or other soft metals will result in iron bits becoming imbedded in the surface resulting in corrosion under the coating and early failure. Iron grit shall be clean and reasonably sharp. Grit that is rusty, noticeably worn, or dull when compared with new grit under a magnification of 10X shall not be used.

4.3.4 Metal spray coating (see 6.4).

4.3.4.1 Metal spray wire. Metal spray wire for use in corrosion-control applications shall conform to MIL-W-6712. Wire surfaces shall be clean and free from scale, corrosion products, oil, or other material which will adversely affect the application, density, or adhesion of the coating. The wire shall be of uniform composition and quality, and free of seams, cracks, nicks, or burns. The wire shall uncoil readily and be free of bends, kinks, or slivers that would prevent

its passage through the spray gun. The wire shall be stored and handled carefully to avoid bends or kinks that would prevent its passage through a spray gun.

4.3.4.2 Metal spray powder. Metal spray powder for use in corrosion-control applications shall conform to MIL-P-83348 or MIL-STD-l 687. Metal spray powder shall be uniform in quality, condition, and color. It shall be dry, granular, free from dust and foreign material, thoroughly blended, nonagglomerated, and shall be capable of producing acceptable metal spray coatings.

4.3.5 Metal spray gases. The following gases shall be used in the metal spray process for corrosion-control applications:

Gas	Specification
Oxygen	BB-O-925
Acetylene	BB-A-106
Propane	--------
MAPP	--------

4.3.6 Seal coat systems.

4.3.6.1 For temperatures above 80°C [175°F). Seal coat system for components whose operating temperature is greater than 80°C (175 F) shall be heat resistant aluminum paint in accordance with DOD-P 24555 or equivalent seal coat approved by NAVSEA (see 4.4.4.3, type I coating system).

4.3.6.2 For temperatures below 80°C (175°F). Seal coat system for components whose operating temperature is less than 80°C (175°F) shall be strontium chromate in accordance with MI L-P-23377, formula 150 paint in accordance with MIL-P-24441 and MIL-P-24441 /1, and formula 151 paint in accordance with MIL-P-24441 and MIL-P-24441/2 (see 4.4.4.3, type II coating system).

4.3.7 ToP coats. Top coats for metal sprayed components, if required, shall be as specified in the applicable contract, work order, specification, ship requirement, or NAVSEA publication (see 6.4).

4.4. Metal .spray Process.

4.4.1 Surface cleaning. Areas to be metal sprayed, and those adjacent thereto, shall be free from grease, oil, paint, corrosion products, moisture or any other foreign material that may contaminate the coating. If contamination is excessive, a trisodium phosphate solution may be used to clean the surface prior to solvent cleaning.

4.4.1.1 Solvent cleaning. Prior to any masking, blasting, or spraying, surfaces that have come in contact with oil or grease shall be solvent cleaned. Solvents shall be in accordance with 4.3.1. Cleaning may be done by wiping, brushing, or spraying. Precautions shall be taken to protect any parts which may be attacked by the solvents.

4.4.1.2 Contaminated surfaces. Surfaces shall be cleaned with a trisodium phosphate solution, rinsed with clear, potable water, and dried after solvent cleaning.

4.4.1.3 Abrasive cleaning.. Preliminary abrasive blast cleaning may be used to remove heavy or insoluble deposits. An inexpensive, disposable abrasive is recommended. Dust and debris shall be removed by dry compressed air "blow-off' prior to anchor-tooth blasting.

4.4.1.4 Heat cleaning. Porous materials that have been contaminated with grease or oil shall be solvent cleaned (see 4.4.1.2). If required, parts shall be heated in vented electric ovens for at least 4 hours to remove grease or contamination remaining after decreasing cleaning process. Steel alloys may be heated to 315°C (600°F) maximum. Aluminum alloys, except age-hardened alloys, may be heated to 150°C (300°F) maximum.

4.4.2 Masking. Masking shall be performed on all adjacent areas which may be affected by abrasive blasting or metal spraying. The mask (tape) shall be applied tightly enough to prevent grit from seeping under the mask. Two layers of tape shall be applied with the second layer at right angles to the first. Protective masking shall be inspected for damage between the abrasive and metal spray processes and replaced if damaged.

4.4.2.1 Special requirements. When a machinery component is not to be disassembled, working and threaded surfaces shall be masked. Unless otherwise noted on applicable drawings for specific surfaces, the following surfaces shall be properly masked or plugged to prevent their being damaged by abrasive blasting or sprayed metal coating:

(a) Machined surfaces that are required to move with respect to each other, such as threads, bearing contacts, gear teeth, and slides.
(b) Surfaces related to component alinement, proper seating, and mounting, such as flange faces, counterbores, and keyways.
(c) Electrical assemblies, such as contacts, relays, and insulators.

4.4.3 Abrasive anchor-tooth blasting for surface Preparation. Prior to metal spraying for corrosion control, the surfaces to be coated shall be prepared by abrasive blasting to provide an anchor tooth for the metal spray.

4.4.3.1 Aluminum oxide or angular chilled iron grit (see 4.3.3) shall be used for the final surface preparation of the substrate. Only aluminum oxide may be reused for anchor-tooth blasting. Prior to reuse, the aluminum oxide shall be screened using a 30-mesh screen, visually inspected for debris and oil contamination, and shall pass the following oil contamination test:

(a) Fill a clean 150 milliliter (5-ounce) vial or bottle half full of screened abrasive particles.
(b) Fill the remainder of the vial or bottle with clean water.
(c) Cap and shake vial or bottle.
(d) Inspect water for oil sheen.
(e) If any oil is observed, the abrasive particles shall not be used in the final anchor tooth blasting process.
(f) Clean blasting equipment, replace blasting material, and retest.

4.4.3 .2 The blasted surface shall have a white metal blast appearance with an anchor tooth (not peened) surface profile of 50 to 75 um (2 to 3 roils) (see figure 3) and validated (measured) with profile tape and a dial micrometer. Blasting shall be done in accordance with SSPC No. 5. A white metal blast cleaned surface finish is defined as a surface with a gray-white, uniform metallic color, slightly roughened to form a suitable anchor pattern for coatings. The surface, when viewed using a magnification of 10X, shall be free of oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint, or any other foreign matter. The color of the clean surface may be affected by the particular abrasive medium used. Photographic or other visual standards of surface preparation shall be used to further define the surface if specified in the contract. Abrasive blasted surfaces shall not be allowed to come in contact with contaminated surfaces prior to completion of metal spray and sealing processes. Prepared surfaces shall be handled only with clean gloves, rags, or slings. Contact with any oil or grease (such as touching with a bare hand) will result in failure of the coating. Blasting shall not be so severe as to distort the component being prepared for metal spray. The slightest presence of oil oxidation or other foreign material on the surface to be sprayed will result in separation of the metal spray coating.

4.4.4 Metal spraying.

4.4.4.1 Surface Protection. The metal spray operation shall be started within 4 hours after anchor-tooth surface preparation for steel has been completed and shall be finished within 6 hours. The metal spray operation on aluminum shall be started within 2 hours after anchor-tooth surface preparation has been completed and shall be finished with 4 hours. If the steel or aluminum substrate temperature is not greater than 5°C (1O°F) above the dew point, no metal spraying shall be conducted. If more than 15 minutes, but not over 4 hours is expected to elapse between the surface preparation and the start of the metal spray process, or if the part must be moved to another location, the prepared anchor-tooth surface shall be protected from moisture, contamination, and fingermarks, Wrapping with clean paper will normally provide adequate protection. When specified in the contractor other guidance documents, for periods longer than 4 hours, a flash coat of metal spray (at least 25 pm (1 mil)) shall be used to protect the surface until final metal spray can be applied. If the period exceeds 6 hours for steel or 4 hours for aluminum, or if other contamination or deterioration of the surface occurs, the surface shall be reblasted in accordance with 4.4.3.

4.4.4.2 Air quality. Any of the following procedures and equipment may be used to monitor water content of the compressed air:

(a) Open a valve downstream of the filter/dryer components slightly, allowing air to vent with a slightly audible flow into an open dry container for 1 minute. Any wetting or staining will indicate moisture or contamination.
(b) Repeat (a) above using a clean white cloth. Any wetting or staining will indicate moisture and contamination.
(c) An electrolytic hygrometer having an indicator graduated in p/m on a range which is no greater than ten times the maximum specified moisture content.
(d) A frost point analyzer in which the temperature of the viewed surface is measured at the time frost first begins to form.

(e) A piezoelectric adsorption hygrometer on a range which is no greater than ten times the specified maximum range.

Techniques (a) and (b) above are primarily for use in the field, and (c), (d), and (e) for shop monitoring instruments.

4.4.4.3 Seal coating system application. The metal coating shall be applied in multiple layers, and in no case shall less than two crossing passes, at right angles, be made over every part of the surface. The sprayed metal shall overlap on each pass of the gun to assure uniform coverage. A type I coating system application for high temperature components (see 4.4.5, category 1) shall consist of 250 to 375 pm (1 O to 15 roils) of metal sprayed aluminum plus the appropriate seal coat (see 4.3.6.1). A type II coating system application for topside equipment (see 4.4.5, category 11) and interior wet spaces (see 4.4.5, category 111) shall consist of 175 to 250 um (7 to 10 roils) of metal sprayed aluminum or zinc plus the appropriate seal coat (see 4.3.6.2). The spray gun shall be held 125 to 200 mm (5 to 8 inches) from the surface being sprayed (see gun manufacturer's recommendations for optimum spray distance). The angle of spray stream to the surface being coated shall be as close to 90 degrees as possible, and never less than 45 degrees. When spraying complex geometric shapes, the operator shall plan for (by masking) and accomplish spraying to minimize overspray onto areas of the component where no coating is desired. During the metal spray operation, the temperature of the object being sprayed shall not exceed 350°F. Cooling during the coating operation maybe accomplished by use of blast of clean dry air, carbon dioxide, or other suitable gas introduced near, but not directly on the area being sprayed. The metal spray operation shall be interrupted only to measure thickness or temperature, or to permit cooling to prevent overheating. See 4.1.6 for personal protection.

4.4.4.4 Coolirm Process. Under normal conditions, the sprayed object shall be allowed to cool to room temperature at a normal rate. If required, accelerated cooling may be accomplished with a blast of clean dry air, carbon dioxide, or other suitable gas. In any case, the air or gas shall be maneuvered to obtain a uniform cooling rate over the entire metal spray area. Under no circumstances shall the component be quenched with liquid to accelerate cooling.

4.4.4.5 Seal coat application. Seal coats used shall be dependent on the normal operating temperature of the component to be metal sprayed (see 4.3.6), and as specified (see 6.4). Two coats of 38 pm (1.5 roils) dry film thickness (dft) shall be applied as shown in figure 4 for type 1 system (see 4.3.6.1). The seal coat for type II system shall be a coat of strontium chromate 13 to 19 pm (0.50 to 0.75 roil) dft; a coat of formula 150 paint 50 to 75 pm (2 to 3 roils) dft; a coat of formula 151 paint 50 to 75 pm (2 to 3 roils) dfi; and a color top coat as required for the area (see 4.3.6.2). Type II system application is shown in figure 5.

4.4.5 Approved applications of metal spray coatings for corrosion control. The following is a list of approved applications of metal spray coatings for corrosion control on Navy surface ships:

Categorv I - machinery space components:

(a) Aluminum coating 250 to 375 um (1O to 15 roils) thick:
 (1) Low pressure air piping.

(2) Steam valves, piping and traps (except steam turbine control valves).
(3) Auxiliary exhaust (such as stacks, mufflers, and manifold).
(4) Air ejection valves.
(5) Turnstile.

Category II - topside weather equipment:

(a) Aluminum or zinc coating -175 to 250 pm (7 to 10 roils) thick.
(1) Aircraft and cargo tie downs.
(2) Aluminum helo decks.
(3) Stanchions.
(4) Scupper brackets.
(5) Deck machinery coatings and foundations.
(6) Chocks, bitts, and cleats.
(7) Pipe hangers.
(8) Capstans/gypsy heads (except wear area).
(9) Rigging fittings (block and hooks).
(10) Fire station hardware.
(11) Lighting fixtures and brackets.

Category Ill - interior wet spaces:

(a) Aluminum or zinc coating -175 to 250 um (7 to 10 roils) thick
(1) Decks in wash rooms and water closets.
(2) Pump room deck and equipment support foundations.
(3) Fan room decks and equipment support foundations.
(4) Water heater room decks and equipment support foundations.
(5) Air conditioning room decks and equipment support foundations.
(6) Deck plate supports.
(7) Machinery foundations.
(8) Boiler air casings (skirts).

4.4.6 Prohibited applications of metal spray coatings for corrosion control. Metal sprayed coatings for use in corrosion-control applications are intended for selected application to steel and aluminum surfaces. Metal spray coatings for corrosion-control applications shall not be used for the following:

(a) Plastic, rubber, painted surfaces.
(b) Internal surfaces of moving machinery (example: pump casings, valves, etc.)
(c) Brass, bronze, copper-nickel, or monel surfaces.
(d) Stainless steels, 17-4PH, 15-4PH.
(e) Surfaces subject to strong acids or bases (example: aircraft catapult slides).
(f) Threads of fasteners.
(g) Valve stems.

(h) Within 20 mm (3/4 inch) of surfaces to be welded.
(i) Steel alloys with yield strength greater than 827.4 megapascals (MPa) (120,000 lb/in^2).
(j) Nonskid deck coatings (except as approved by NAVSEA for research and development evaluation).
(k) Exterior underwater hull surfaces.
Sanitary tanks interior.

5. DETAILED REQUIREMENTS

5.1 Certification. Prior to the utilization of this spraying procedure, Naval facilities and contractors shall submit a request for certification and obtain approval of certification of facilities and spray operators from the NAVSEA authorized agent prior to award of contract. Data submitted shall not relieve the facility or contractor of responsibility for conformance with all requirements of this standard. Contractors shall be responsible for similar qualification of ail subcontractors. Certification may be terminated in the event NAVSEA or the authorized agent has evidence that all the requirements (facility, operator, and product quality assurance) of this standard are not being met. The applicable work covered by this standard may be suspended upon written notification by the authorized agent, until it has been demonstrated that such deficiencies have been corrected.

5.2 Facilities. Each facility, whether Government or privately owned, shall provide written evidence of compliance to the requirements of this standard to the NAVSEA authorized agent prior to award if contract. The NAVSEA authorized agent shall inspect the facility to verify that all requirements are met. The requirements address working areas, abrasive blasting equipment, and metal spraying equipment. Facilities meeting the requirements of this standard shall be deemed certified (see 5.1) to carry out the contractual obligations for the contracted metal spray procedure. Recertification will not be required except as noted in 5.1

5.2.1 Working areas. The following minimum requirements shall be met for shore side facility work areas. Work carried out aboard ship shall be conducted in accordance with NAVSEA S9086-VD-STM-000, Chapter 631 and this standard where applicable.

(a) Abrasive blasting areas: If abrasive blasting is carried out in an enclosed area other than a designated blasting booth, the air in the enclosed area shall change at least once per minute. Additional safe breathing apparatus (operator's hood) shall be used.
(b) Metal spraying areas:
  (1) Spray booths: The wet spray booth shall be constructed with surfaces angled to deflect the metal spray blast inward and not blow dust out of the booth. The booth shall be equipped with a wet collector and an exhauster that will maintain air flow of at least 61 cubic meters per minute per square meter (200 cubic feet per minute per square foot) of booth opening into the booth entrance.
  (2) Enclosed areas: Enclosed areas shall be equipped with a water-wash dust collector with a capacity in cubic meters per minute at least three times the volume of the enclosed space. Air inlets to the

areas shall be located near the ceiling on the side opposite the working area (bench). The air exhaust shall be located at or near the floor along the entire side of the room adjacent to the working area. The duct work shall be large enough to permit air velocities greater than 610 meters (2000 feet) per minute. An air respirator mask shall be provided for the operator, as well as eye and ear protection.

(3) Open areas: Metal spraying in open areas shall be carried out only when suitable eye and ear protection and an air respirator are being used.

5.2.2 Abrasive blasting equipment. The following list of equipment identifies the minimum required for performing abrasive blasting operations. All equipment shall be in satisfactory working order.

(a) Blaster utilizing air free of oil and moisture (see 4.2.1.2).
(b) Steel blasting table or cabinet.
(c) Oil and moisture separator.
(d) Air pressure regulators with pressure gages.
(e) Air volume indicator.
(f) Blast nozzle equipped with a dead-man valve.
(g) Abrasive (see 4.3.3).
(h) Sample metal coupons.
(i) Press-O-film (available from TESTEX, Inc.), or equivalent.
(j) Caliper *or* dial micrometer.

5.2.2.1 Special clothing. The following clothing shall be worn when blasting operations are performed in an enclosed space:

(a) Helmet with forced air supply.
(b) Canvas jacket.
(c) Canvas trousers.
(d) Steel toed work shoes.
(e) Rubber or leather gloves.

5.2.3 Metal spray equipment. The list of equipment for metal spray operations shall meet the requirements of 4.2.2 for the applicable spraying system. All equipment shall be in satisfactory working order.

5.2.3.1 Protective equipment. The following protective equipment shall be worn for metal spray operations:

(a) Air respirator.
(b) Noise protection (ear muffs or plugs).
(c) Eye protection (see 4.1 .9).

5.2.3.2 Additional equipment. The following equipment is not required for certification but may be necessary to complete the thermal spray process:

(a) Masking materials.
(b) Surface pyrometer.
(c) Magnetic thickness gage.
(d) Eddy current gage.
(e) Crane or handling equipment.

5.3 Application Procedure certification. Certification of the application procedure will be given those facilities demonstrating the ability to successfully carry out the proposed procedure. The requirements set forth herein shall be met prior to obtaining certification. Electric arc wire spray systems are acceptable only where it can be demonstrated that the requirements set forth in this standard can be certified. Certification is required for each new application procedure. Recertification will not be required except as noted in 5.1.

5.3.1 Application Procedures. Contractors, prior to award of contract, and Naval activities shall prepare written application procedures, and perform tests, as required, to obtain certification of these procedures. The written procedures shall include a description of the proposed application procedure and a listing of the various processes (such as blasting, metal spraying, inspection, and sealing) performed. Record forms shall be provided as evidence of the performance of quality assurance examinations.

5.3.2 Application Procedure approval. Prior to the utilization of a metal spraying procedure, the contractor shall demonstrate the procedure, with the supporting test qualification data, to the authorized agent for approval. Data submitted shall not relieve the contractor of responsibility for conformance with other requirements of this standard. Contractors shall be responsible for similar certification of all subcontractors.

5.3.3 Certification test recmirements. Application procedure certification shall consist of a visual examination, bend test, bond test, and shape test of metal sprayed specimens prepared by an operator using the proposed procedure. Specimens for the testing shall be prepared in accordance with 5.6.1 and the written application procedures. For the visual examination and bend test, four specimens shall be tested in accordance with 5.6.2 and 5.6.3. Results of the test shall conform to the requirements of 5.3.3.1 and 5.3.3.2. For the bond test, five specimens shall be prepared and tested in accordance with ASTM C 633, and shall meet the requirements of 5.3.3.3.

5.3.3.1 Visual examination requirements. The metal sprayed coating prior to sealing shall have a uniform appearance. Surface defects of the metallized coating shall be limited to small nodules not to exceed 1.1 mm (0.045 inch) in diameter and shall not exceed 0.6 mm (0.025 inch) in height above the surrounding sprayed surfaces. The coating shall not contain any of the following:

(a) Blisters.
(b) Cracks.
(c) Chips or loosely-adhering particles.

(d) Oil or other internal contaminants.
(e) Pits exposing the undercoat or substrate.

5.3.3.2 Bend test. No disbanding, delamination, or gross cracking of the coating shall occur due to bending. Small hairline cracks or alligatoring of the coating in the vicinity of the bend are permissible. Figure 6 illustrates acceptable and nonacceptable bend test results.

5.3.3.3 Bond test. The bond strength of the metallized coating on the individual test specimens shall be 10.3 MPa (1 500 lb/in^2) or greater. The average bond strength of five samples of the metallized coating on the tested specimens shall be 13.8 MPa (2000 lb/in^2) or greater.

5.3.3.4 Shape test. The thickness of the metallized coating shall meet the requirement of this standard for the metal spray process and shall be 0.25 to 0.40 mm (0.01 O to 0.015 inch).

5.4 Certification of metal spray operators. This section provides the requirements for certification of metal spray operators. Each operator shall be certified by demonstrating, as specified herein, the ability to apply the specified coating system, using the applicable spray process, and correct and safe usage of the equipment.

5.4.1 Responsibility. Prior to invoking this standard, each activity, contractor, or subcontractor, shall establish that each metal spray operator to be employed in the use of metal spray for corrosion-control applications has been certified by demonstrating the ability to produce satisfactorily in accordance with 5.3.3.

5.4.2 Operator certification.

5.4.2.1 Certification tests. The operator shall prepare specimens in accordance with 5.6.1, which in turn, shall meet the test requirements set forth in 5.3.3.

5.4.2.2 Limits of certification. Operators meeting the requirements for the certification tests shall be deemed “certified operators” with the coating system and spray process used in the application procedure testing.

5.4.2.3 Retest of operators. An operator failing the initial certification tests may be permitted to perform one retest for each type of test failed. If the operator fails the retest, he shall not be certified until completion of training or retraining and subsequent complete certification retesting.

5.4.3 Maintenance of operator certification.

5.4.3.1 Term of certification. Operator certification shall be retained as long as a period of 6 months does not lapse between production use of the applicable metal spray process. Production use shall be defined as performing metal spraying operations at least 8 hours in a consecutive 30-day period.

5.4.3.2 Recertification. Operators whose certification has lapsed may be recertified by satisfactorily completing the certification tests.

5.4.3.3 Special. Recertification testing may also be required at any time an operator's performance is questionable as evidenced by production quality assurance.

5.5 Production quality assurance. Production quality shall be assured by certification and the maintenance of production records and an inspection system by the performing activity, contractor, or subcontractor. Production records and inspection requirements shall be subject to modification by the contracting agency as stated in the contract (see 6.4).

5.5.1 Production records. The performing activity, contractor, or subcontractor shall maintain production records for lot sizes specified by the contracting agency. A production record form shall be prepared prior to commencement of work by the performing activity, contractor, or subcontractor. The record shall assign responsibility and provide accountability for performing work and assuring quality control. These records shall be available for review and audit by the authorized agent. The sample record form shown in figure 7 may be used as a guide for preparing production records.

5.5.2 Inspection system. Sampling and inspection of end items shall be as specified in the contract, and at a minimum, shall consist of a comparison coupon bend test, visual inspection, and thickness measurement as directed herein. In the event of failure by a sample item during any test, the item shall be recoated by repeating the entire application procedure. Each item of the lot from which the failed sample item was drawn shall be subjected to the inspection system requirements. In the event the authorized agency suspects failure of a coating job, the knife-peel test (see 5.5.2.3) or the adhesion test (see 5.5.2.4) can be used to determine if the coating will meet the requirements of this standard. The adhesion testis applicable only to category III items specified in 4.4.5.

5.5.2.1 Visual inspection. Each sample item shall be examined visually at a magnification of 10X. The coating shall have a smooth, uniform appearance. The coating system shall not contain any blisters or loosely adhering particles, nor shall it contain any cracks, pinholes, or chips which expose the metal substrate. Areas of apparent nonadherence (blistering, loose particles, cracks, or chips) shall be subjected to the knife-peel test (see 5.5.2.3). Coatings displaying any of the above discontinuities shall be removed to base metal and the coating system replaced.

5.5.2.2 Thickness measurement. Thickness measurements shall be performed on each sample item by means of a calibrated thickness gage, or by direct caliper measurement of the increased dimension. Required thickness of the coating system and tolerances shall be specified in this standard.

5.5.2.3 Knife-peel test. The knife-peel test consists of a single knife cut 40 mm (1.5 inches) long through the metal spray coating to the substrate. If any part of the coating system along the cut can be separated from the base metal using the knife, the bond shall be deemed unsatisfactory.

5.5.2.4 Adhesion test. An aluminum or steel dolly (3.2 square centimeters (0.50 square inch) surface contact area) shall be cemented to the metal sprayed surface. After curing, the dolly shall be pulled off the surface with a calibrated adhesion tester. An adhesive failure less than 6.9 MPa (1000 lb/in^2) indicates a poor metal coating, and therefore, shall not be passed. This test

shall be used in a noncritical area of the job and can be recoated with the topcoat if no failure occurs.

5.5.3 Periodic inspection. Prior to commencement of each day's production run, a sample coupon shall be prepared in accordance with 5.6.1.1. and tested in accordance with 5.6.3. The specimen shall meet the requirements of 5.3.3.2. In the event of failure, the cause shall be identified, and the problem corrected. This inspection is included to identify problems which can lead to subsequent failure of a production run.

5.6 Certification test procedures.

5.6.1 Preparation of the test specimens.

5.6.1.1 Specimens for visual and bend tests. Four panels approximately 75 to 50 by 1.25 mm (3 inches by 2 inches by 0.050 inch) (minimum) shall be sprayed on one of the large faces using the appropriate spraying procedure and metal substrate. The coating thickness shall be 175 to 250 um (7 to 10 roils). The same panel may be used for visual and bend test.

5.6.1.2 Specimens for bond test. Five specimens for the bond test shall be machined and prepared according to the requirements of ASTM C 633 and this standard.

5.6.1.3 Specimens for shape test. One specimen shall be manufactured in the shape of a "T" 75 by 75 by 13 mm thick by 150 mm long (3 inches by 3 inches by 1/2 inch thick by 6" inches long). Another specimen shall be cut from a length of 50 mm iron pipe size (ips) pipe, 150 mm long (2 inch ips pipe, 6 inches long). The specimen material shall be the applicable substrate and shall be coated using the spraying procedure of 5.6.1.1.

5.6.2 Visual examination. Each of the prepared panels shall be examined under magnification of 10X. The surface appearance shall meet the requirements of 5.3.3.1.

5.6.3 Bend test. The sprayed panels shall be bent approximately 180 degrees on a 13-mm (1/2 inch) diameter rod. The coating shall be on the tensile side of the bend. The bend specimen shall be examined *visually* to insure compliance with 5.3.3.2.

5.6.4 Bond test. The bond test specimens (see 5.6.1 .2) shall be tested in accordance with ASTM C 633 for bond strength and the average bond strength of the five specimens. The strength of the individual specimen bonds shall be 10.3 MPa (1500 lb/in^2) or greater. The average bond strength shall be 13.8 MPa (2000 lb/in^2) or greater. Examination of the test specimen shall be conducted after rupture to determine the cause of failure. Anew specimen shall be substituted if examination concludes that the failure occurred at the adhesive-coating interface.

5.6.5 Shape test. The thickness of the sprayed metal coatings shall be measured in sufficient areas to determine that the coating thickness is within the required range (see 5.3.3.4) across the specimen surfaces.

5.6.6 Test results. The results of ail tests and examinations shall be documented and included in the application procedure certification package.

5.7 Records. Records of facility, application procedure, and operator certification, including certification test results and production records, shall be maintained by each performing activity, contractor, or subcontractor. These records shall be available to the contracting agency for review and audit. The performing activity, contractor, or subcontractor shall maintain these records for a period of 6 months after completion of the contract work. Copies of the records shall be made available to the contracting agency upon request. Disposition of the records shall be as agreed upon in the contract.

5.8 Noncompliance. In the event the contracting agency or his representative has evidence indicating that the requirements of this standard are not being met, the applicable work covered by this standard may be suspended at no cost penalty to the Government upon written notification until the contractor has demonstrated that such work deficiencies have been corrected.

6. NOTES

6.1 Applications.

6.1.1 Approved applications. The use of metal spray coatings for corrosion-control applications that have been approved by NAVSEA are listed in 4.4.5. Selection of one of the listed applications does not eliminate the need for the application certification tests required by this standard.

6.1.2 Unauthorized applications. The use of metal spray coatings for corrosion-control applications that are not authorized by NAVSEA are listed in 4.4.6. NAVSEA assistance shall be requested for controlling corrosion in these areas.

6.1.3 Proposed applications. The use of metal spray coatings for corrosion control in areas other than those listed in 4.4.5 require prior approval of NAVSEA.

6.2 Additional precautions. In addition to the safety precautions contained herein, accomplishing abrasive blasting, metal spraying, and sealing on board ship shall be performed in accordance with NAVSEA S9086-VD-STM-OO0, Chapter 631 and NAVSEA S9086-CH-STM-030, Chapter 074. The performing activity, contractor, and subcontractor shall be responsible for insuring that the proper precautions are being observed to preclude personnel injury or machinery damage (including surroundings) prior to accomplishing the required operations.

6.3 Packaging. The performing activity, contractor, or subcontractor shall be responsible for packaging the end item in a manner that will afford adequate protection against damage during direct shipment from the facility to the receiving activity. These packages shall conform to the applicable carrier rules and regulations, as required. Marking information shall be provided on the exterior of the package and shall include the contractor work order number, the nomenclature, facility name and destination. This data may be modified by the contracting agency.

6.4 Ordering data. Acquisition documents should specify the following:

(a) Work is to be performed in accordance with this document.

(b) The use of NAVSEA S9086-VD-STM-OO0, Chapter 631 and NAVSEA S9086-CH-STM-030, Chapter 074 in the case of shipboard work.
(c) Type 1, 11, or Ill abrasive blasting equipment (see 4.2.1.1).
(d) Type of metal spraying system (see 4.2.2).
(e) Type of abrasive blasting particles (see 4.3.3).
Type of metal spray coating(see 4.3.4).
(g) Type of top coat (see 4.3.7).
(h) Type of seal coat (see 4.4.4.5).
(i) The requirement of certification as applicable (see section 5).
(j) The sampling plan for production quality assurance (see 5.5).

Preparing activity:
Navy - SH
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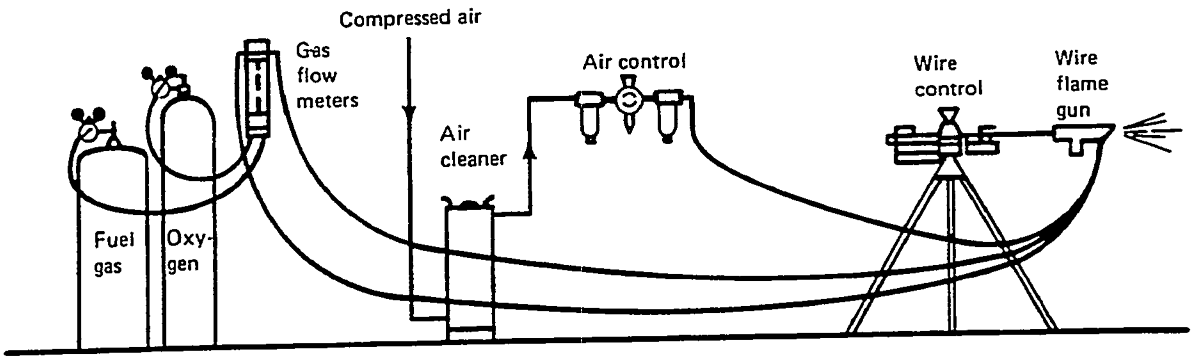
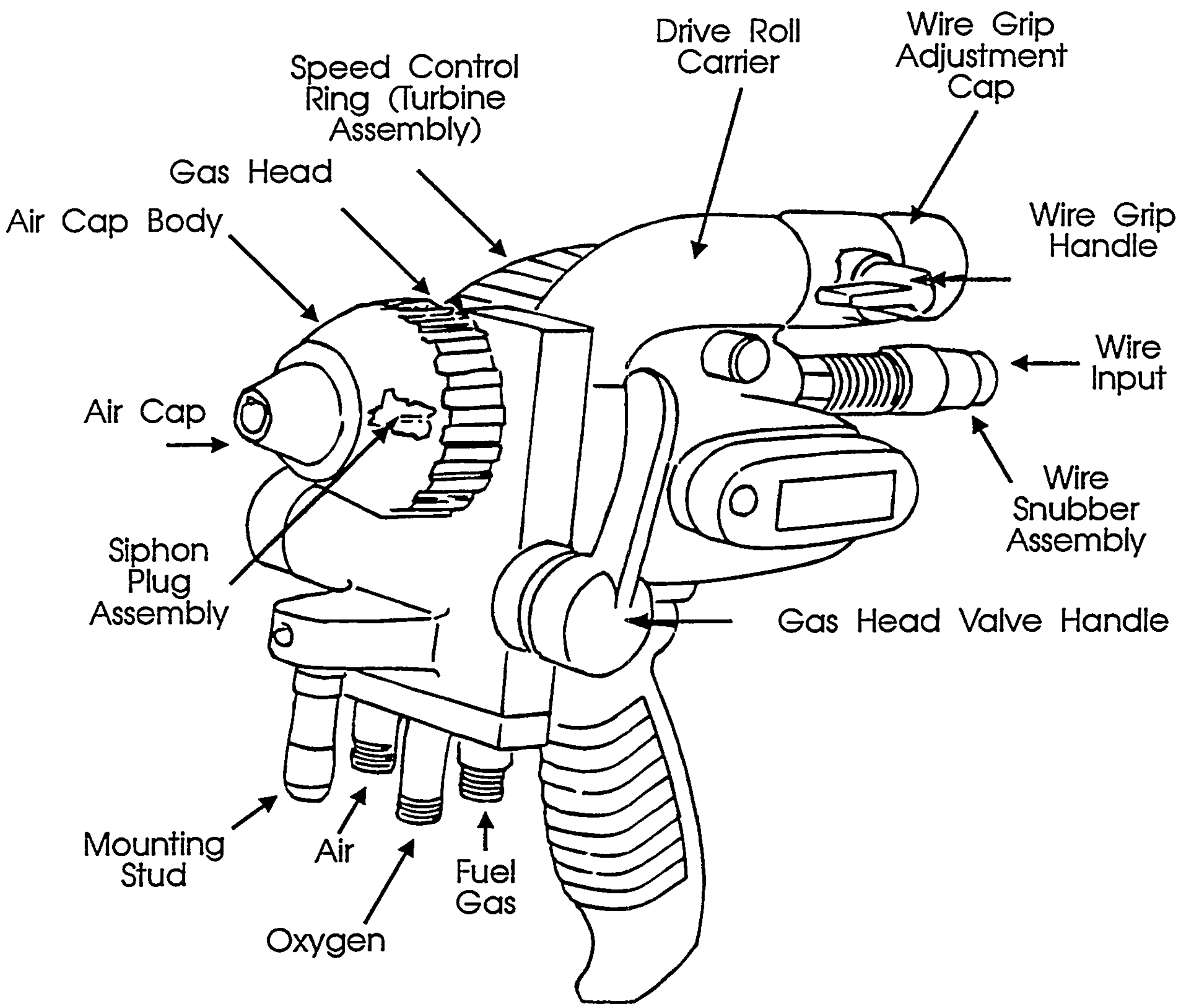


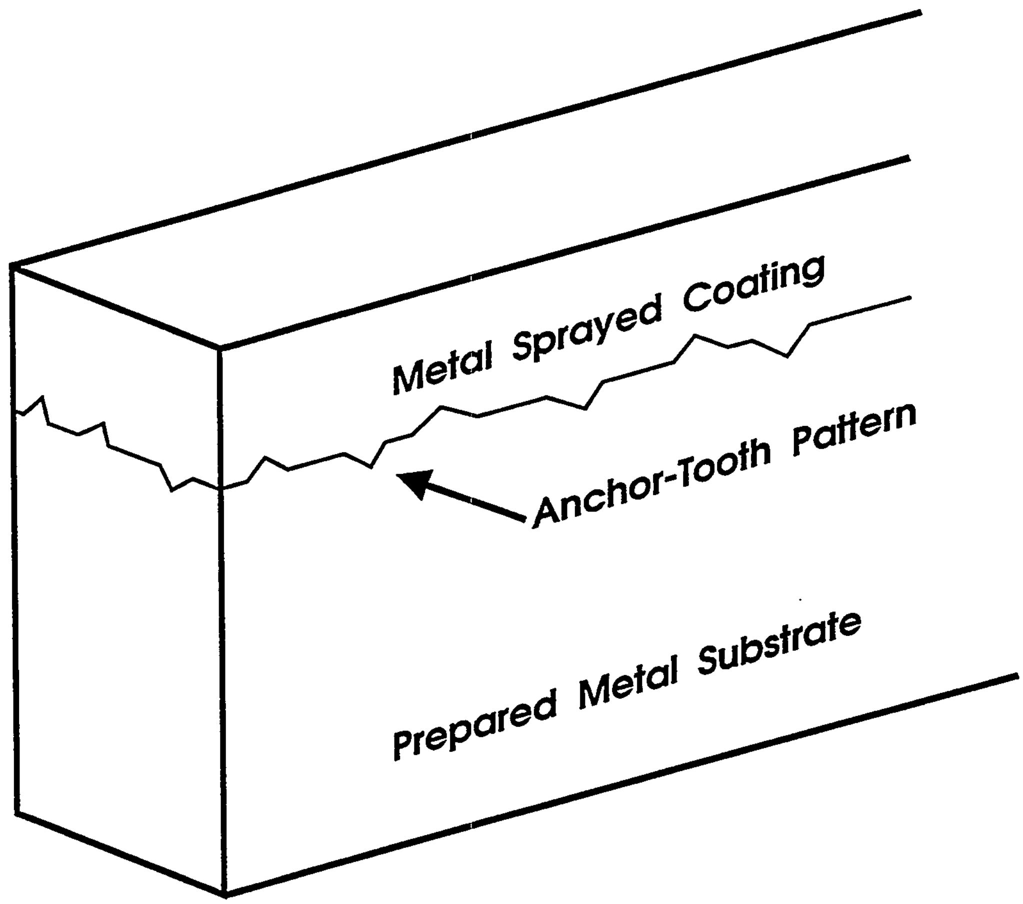
SH 12066

Figure 1. Typical Metal Spray System



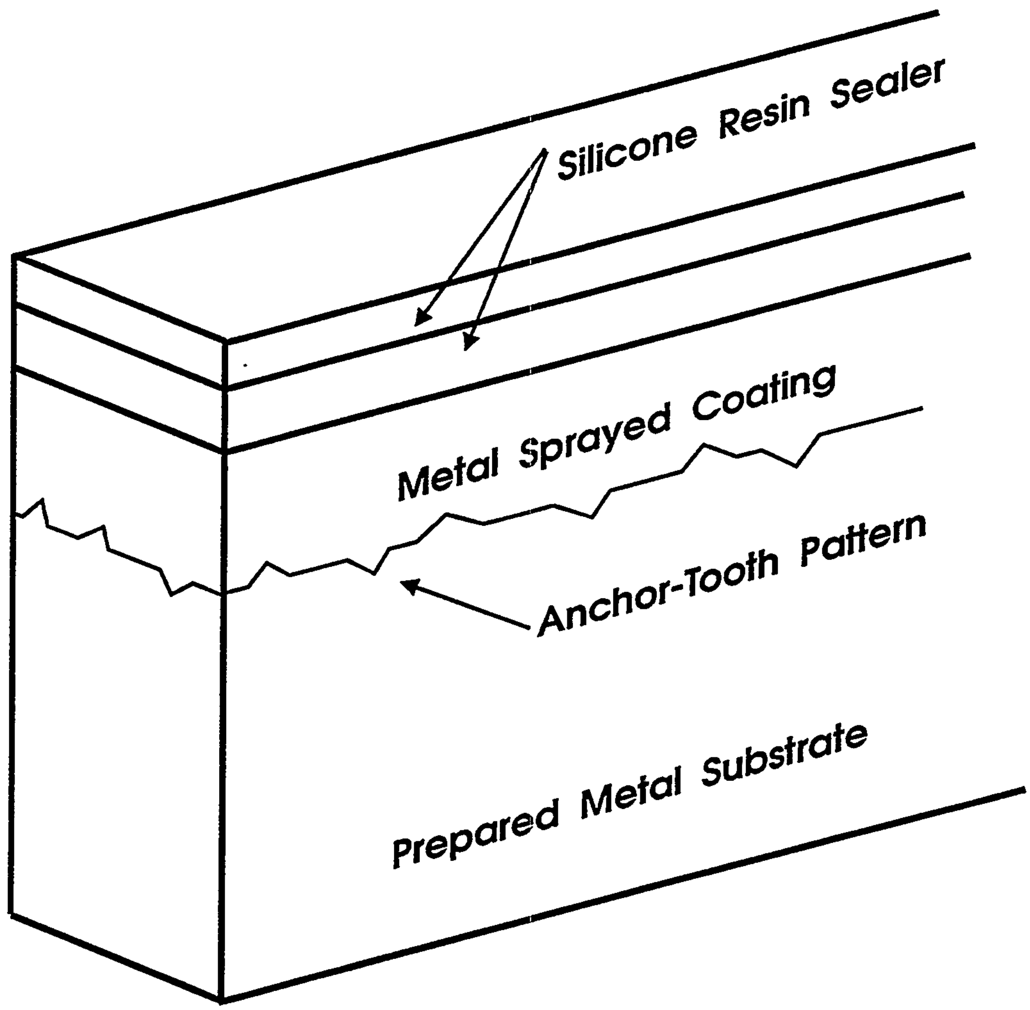
SH 12067

Figure 2. Typical Wire Spray Gun



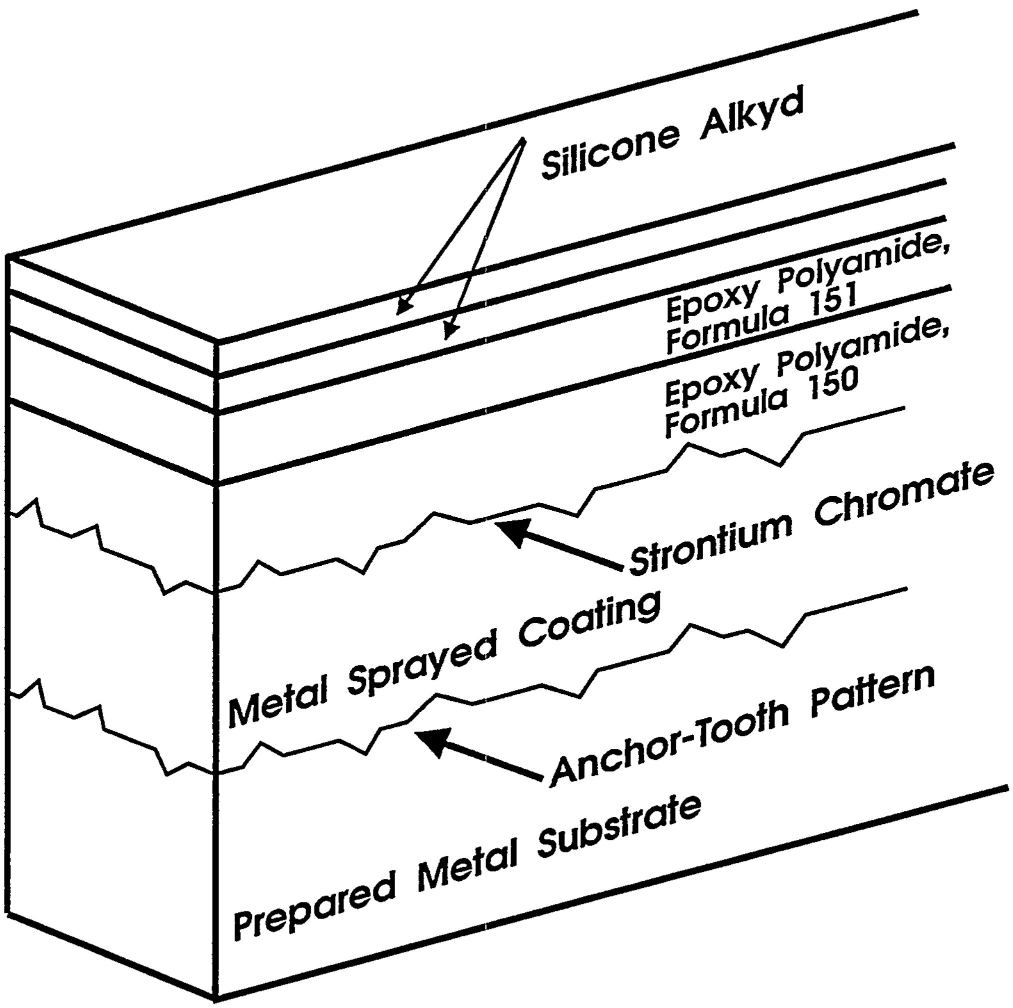
SH 12068

Figure 3. Profile of Anchor-Tooth Pattern



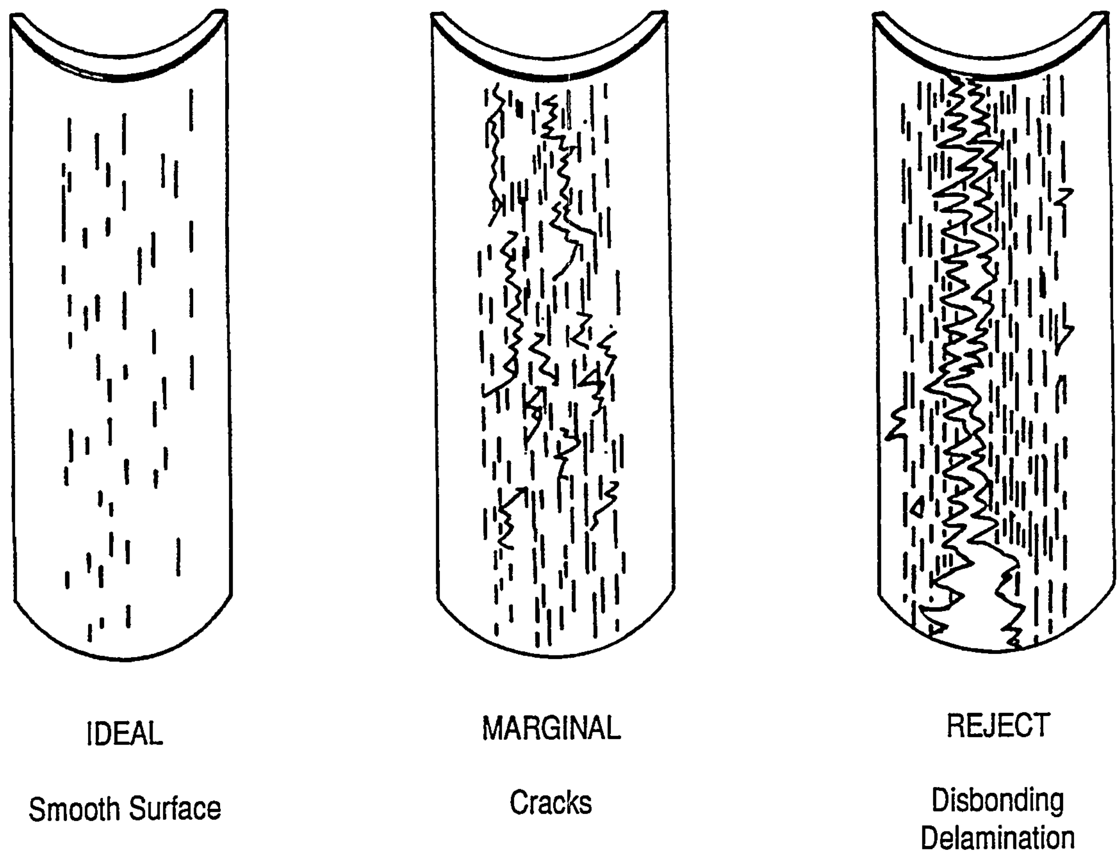
SH 12069

Figure 4. Type I System with Heat-Resisting, High-Temperature Sealer, (Silicone Aluminum Sealer)



SH 12070

Figure 5. Type II System with Low-Temperature Sealer (Epoxy Polyamide and Cosmetic Topcoat)



SH 12071 **Figure 6. Coupon Bend Test Accept/Reject Examples**

1. Job control number ______________________ 2. Date ______________________
3. Ship system ______________________ 4. System component ______________
5. Area to be sprayed ____
6. Masking information (area not to be sprayed) ____________________________
7. Base material (type) ____
8. Preparation methods:

   Cleaning: Degrease solvent: ______________________________________
   Oven bake: temp ____________________; time ____________

   Rough blasting: Grit type and size: ______________________________

   Anchor-tooth blasting: Grit type, size, and profile: _______________

   ____

   Masking information ____

9. Thermal sprayed coating (type and thickness) ____________________________

____

10. Seal coat (types and thicknesses) ______________________________________

____

11. Top coat (type) ____
12. Inspection procedures and results

    Visual examination (inspector initial) ______________________________

____

    Thickness measurement (inspector initial) ___________________________

____

    Knife peel test (inspector initial) ________________________________

____

Item accepted? (Yes/No)

Sprayer's identification

Name/number ____

Inspector's identification

Name/number ____

Figure 7. Metal Spray Report Format

APPENDIX

DATA REQUIREMENTS

10. DATA

10.1 Data requirements. When this standard is used in a contract which incorporates a DI 1423 and invokes the provisions of 7-104.9(n) of the Defense Acquisition Regulation (DAR), th requirements identified below will be developed as specified by an approved Data Item Description (DI 1664) and delivered in accordance with the approved Contract Data Requirements List (DD Form incorporated into the contract. When the provisions of DAR 7-104.9(n) are not invoked, the data sp below will be delivered by the contractor in accordance with the contract requirements. Deliverab required by this standard is cited in the following paragraphs:

Paragraph	Data requirement	Applicable DID	Option
5.3.1, 5.5.1, 5.6.6, and figure 7	Documentation, management/technical support	UDI-A-26199	-----

(Copies of data item descriptions required by the contractors in connection with specific acq functions should be obtained from the contracting activity or as directed by the contracting officer.)

10.1.1. The data requirements of 10.1 and any task in the standard required to be performed t a data requirement may be waived by the contracting/acquisition activity upon certification by the offe identical data were submitted by the offeror and accepted by the Government under a previous cont identical item acquired to this standard. This does not apply to specific data which may be required fc contract, regardless of whether an identical item has been supplied previously (for example, test re

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APPENDIX I:
PHOTOGRAPHS

APPENDIX I

PHOTOGRAPHS

1. Overview of NASSCO's containerized thermal spray facility, including a blast room (1), a spray room (2), dust collector (3), and a portable skid (4).

2. Side view of NASSCO's containerized facility, showing air drying equipment (1), blast equipment (2), dust collection hopper (3), thermal spray booth (4), and a gas bottle storage (5).

3. Looking through the doors of NASSCO's containerized facility. Components are moved by overhead trolley through blast room (far end) and then into thermal spray booths. Gun controls are mounted on door at right.

4. Portable skid to house equipment used for remote work. Skid contains air drying system and supporting equipment for surface preparation and thermal spray.

5. Equipment used to ensure surface profile measurements are within specification tolerance of 2-4 mils prior to aluminum thermal spraying.

6. Magnetic gauge is used to ensure coating thickness is within specified tolerance. Readings are taken frequently during the coating process.

7. Preparing daily bend test coupons. 2 inch x 3 inch coupons are coated and bent in a test fixture to check for proper bond prior to each day's production run.

8. Blast operator prepares surface of machinery foundation prior to thermal spray coating. Aluminum oxide grit is recovered and recycled via floor grating in containerized blast room.

9. Thermal spray operator applies aluminum coating to machinery foundation using combustion wire gun. Edges to be welded are masked prior to spraying.

10. Thermal spray operator applies epoxy seal coat to newly thermal sprayed foundation. Final paint system is then applied over seal coat.


4
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2
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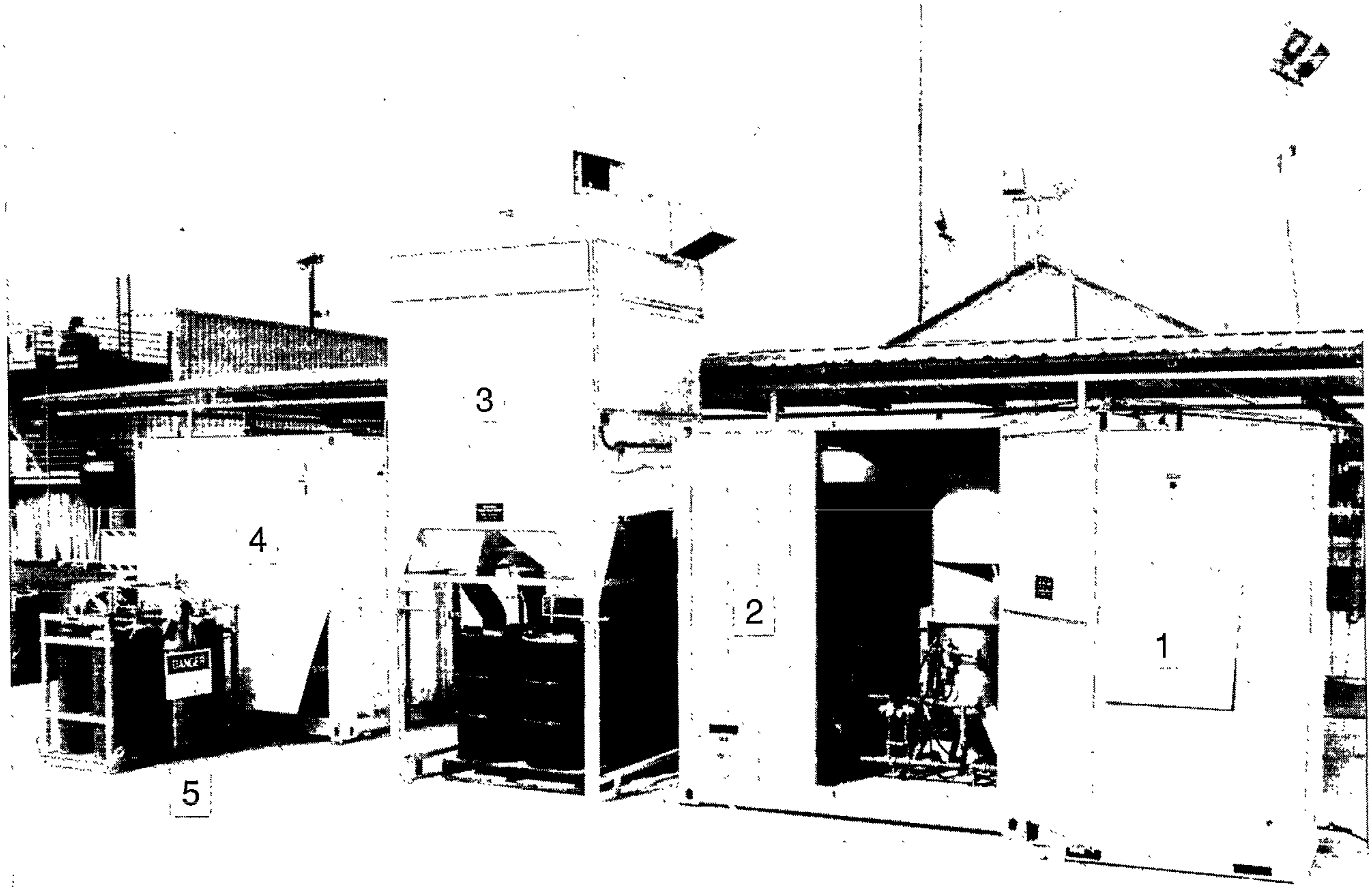
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DANGER
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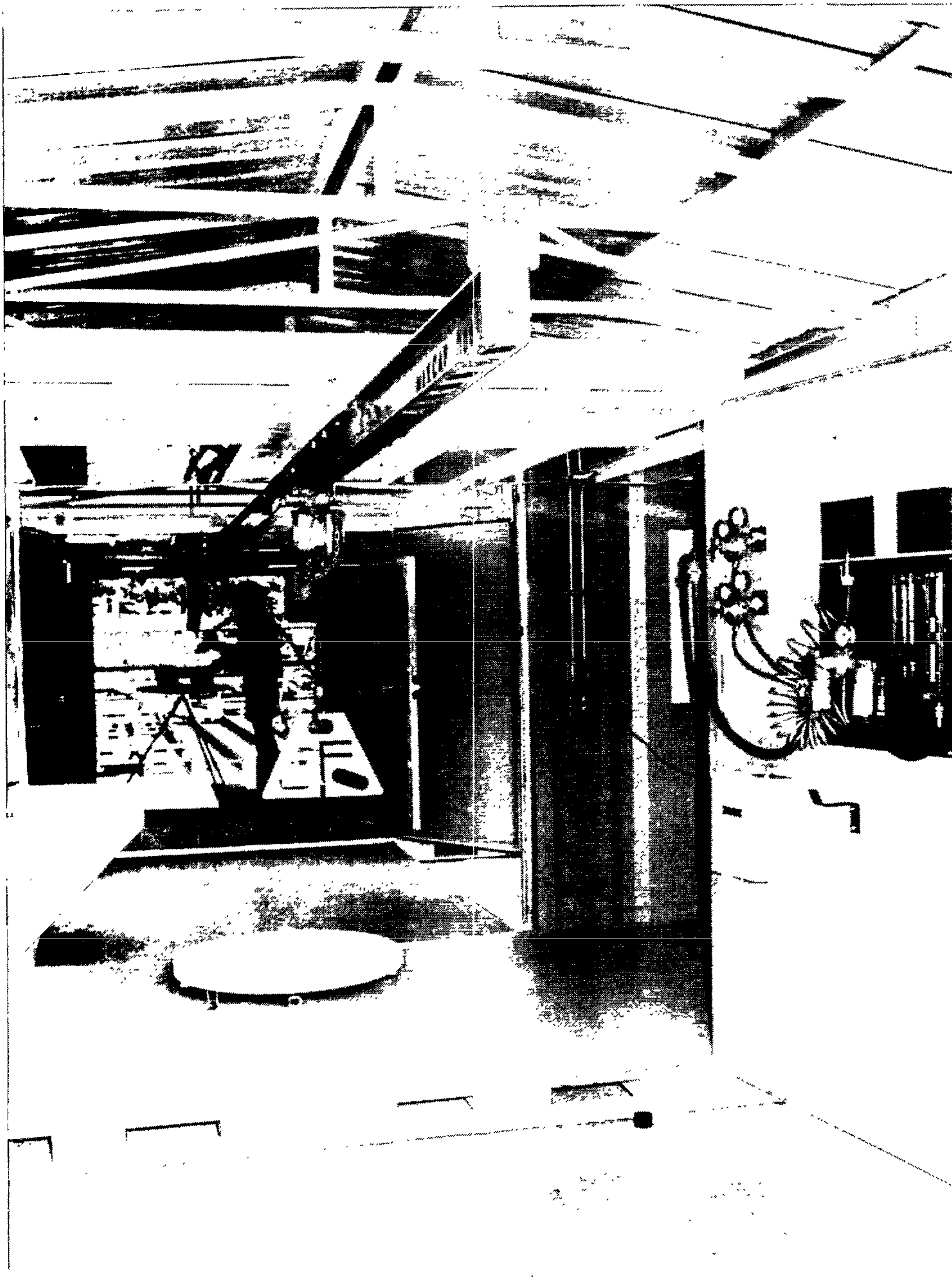
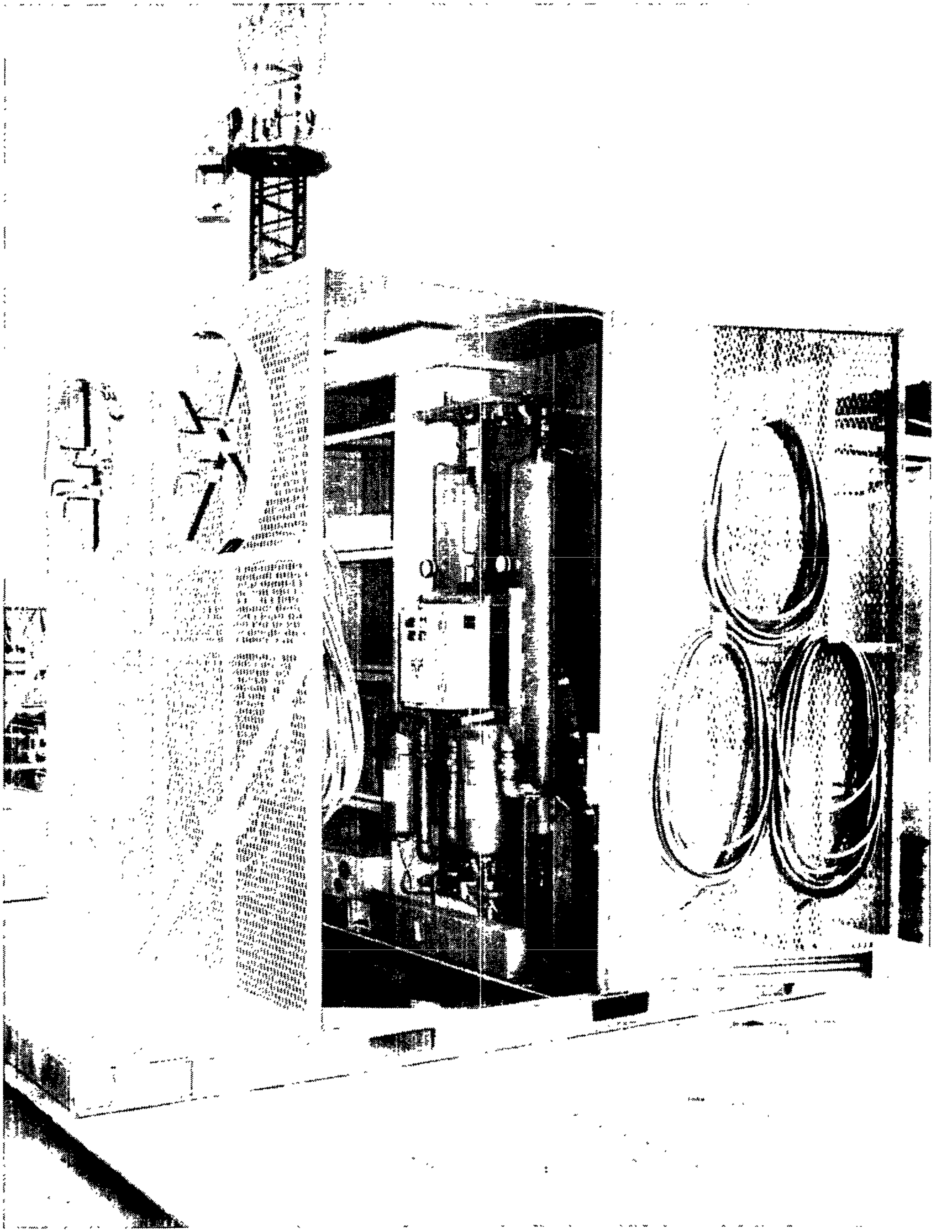
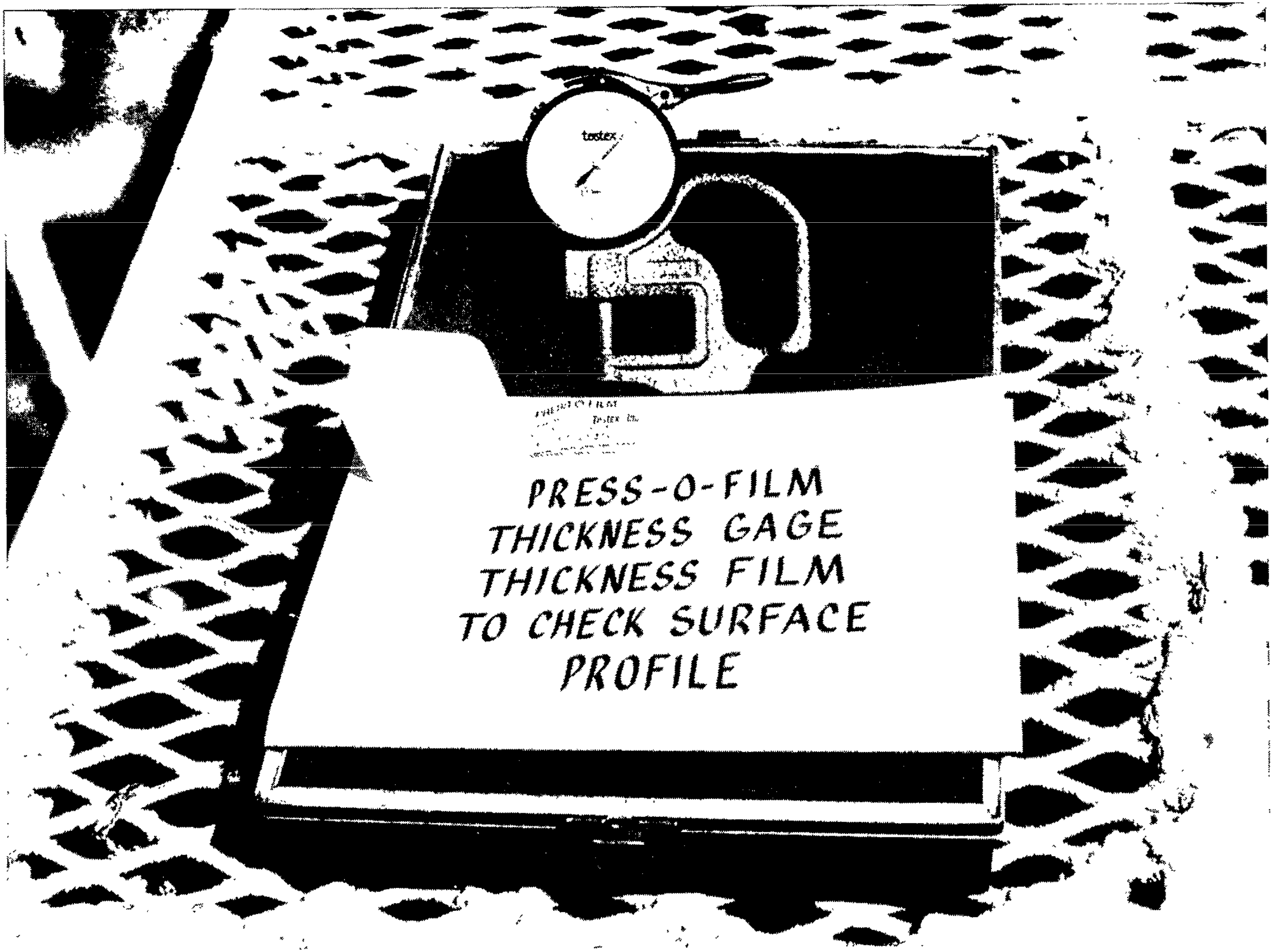
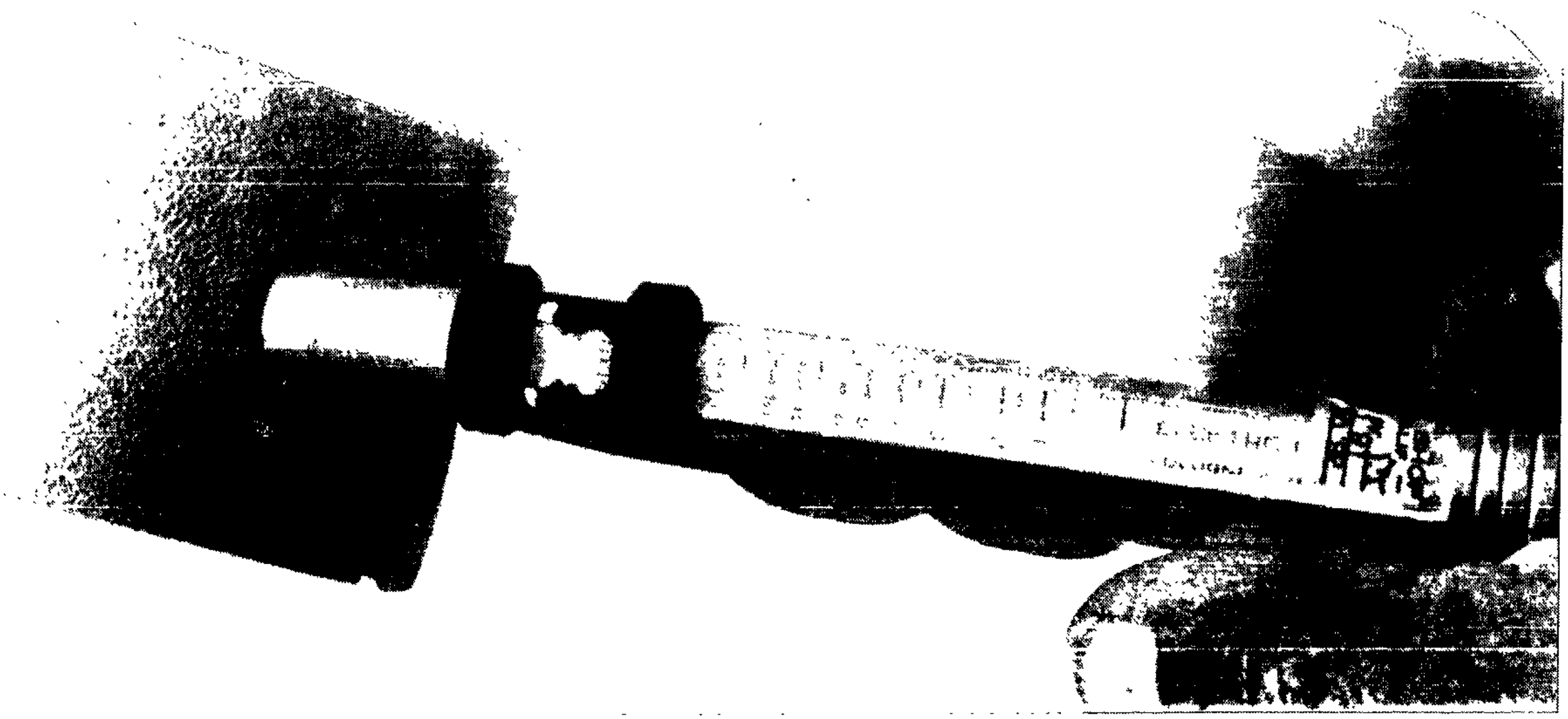
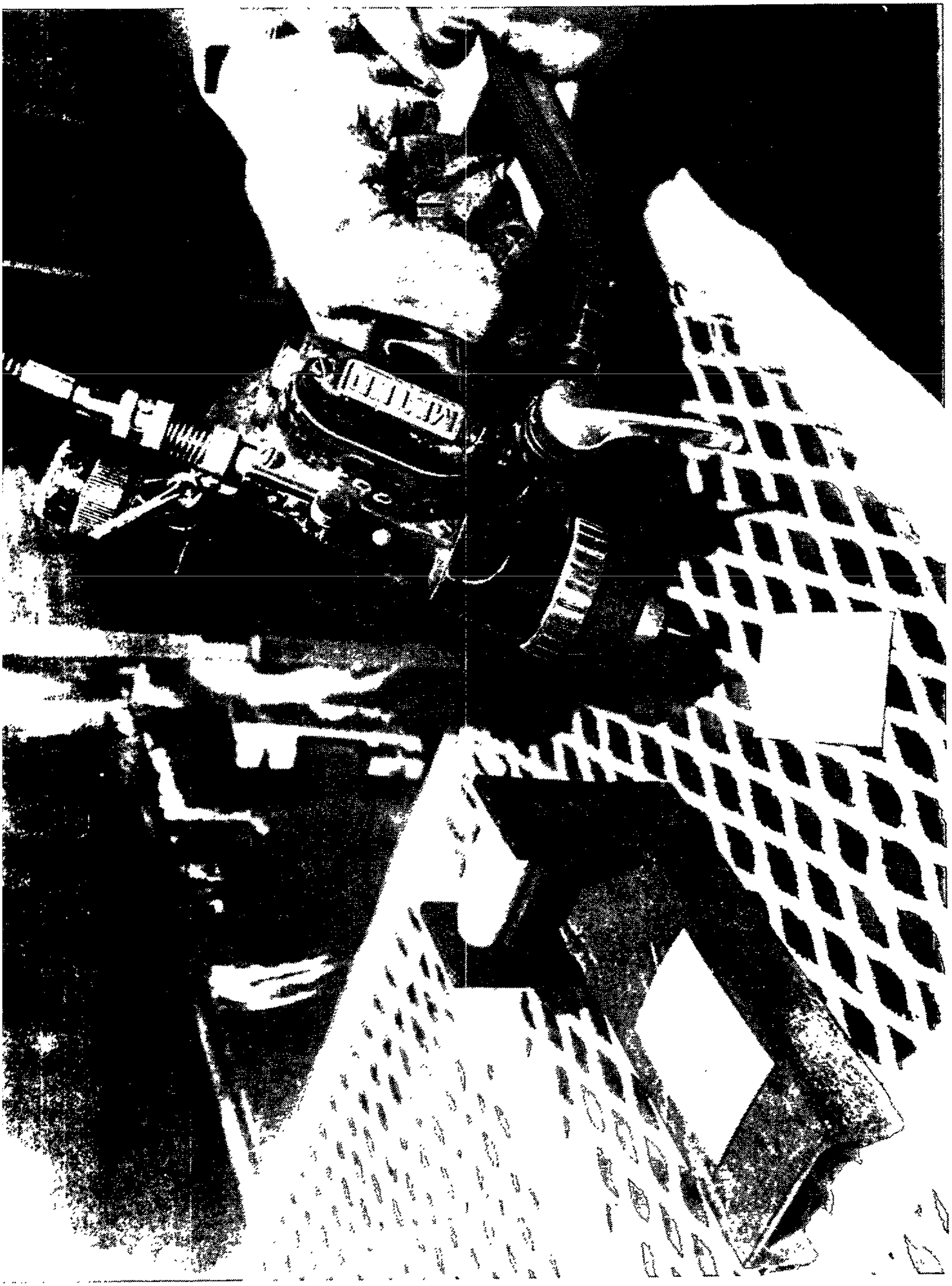


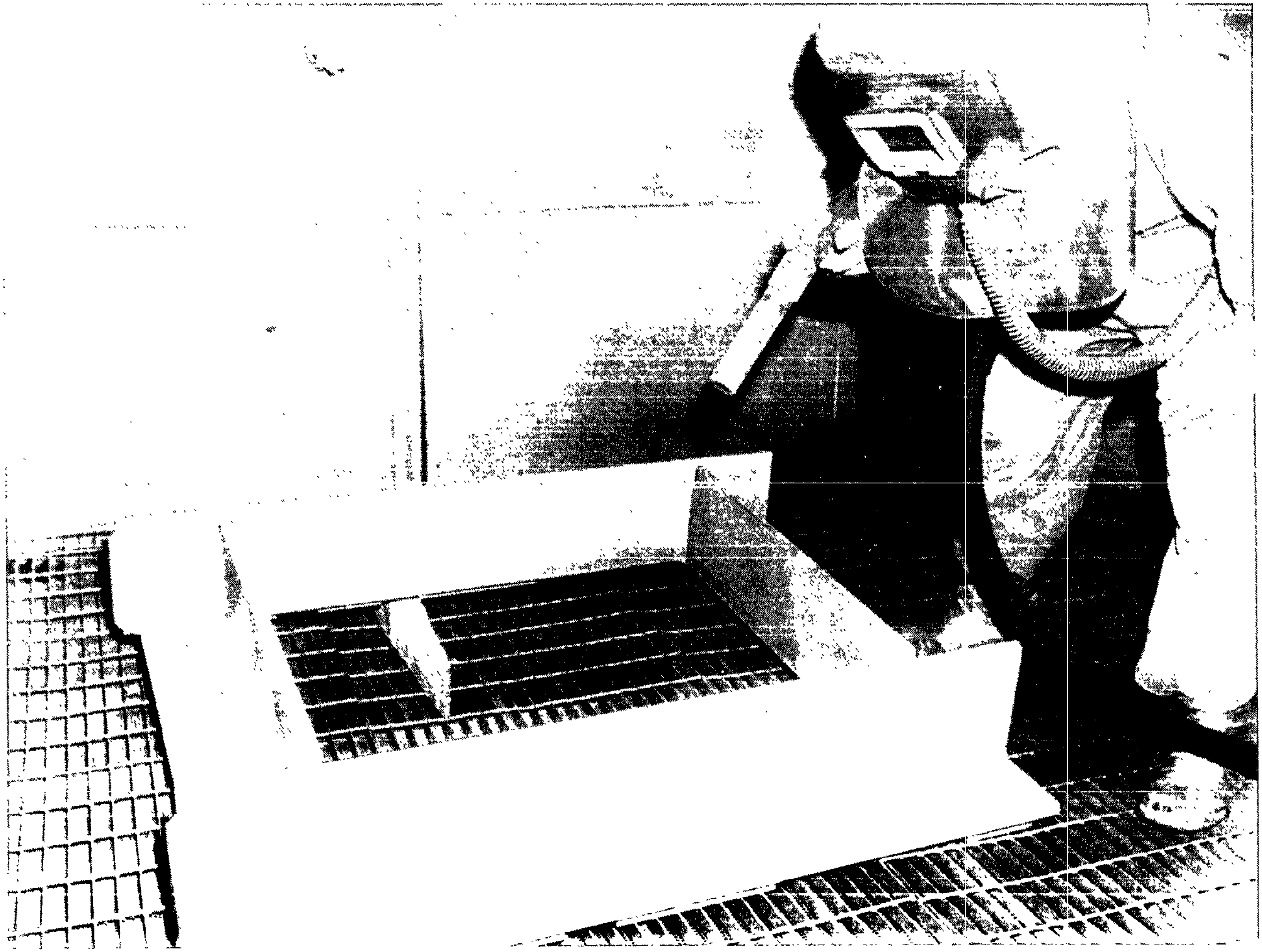


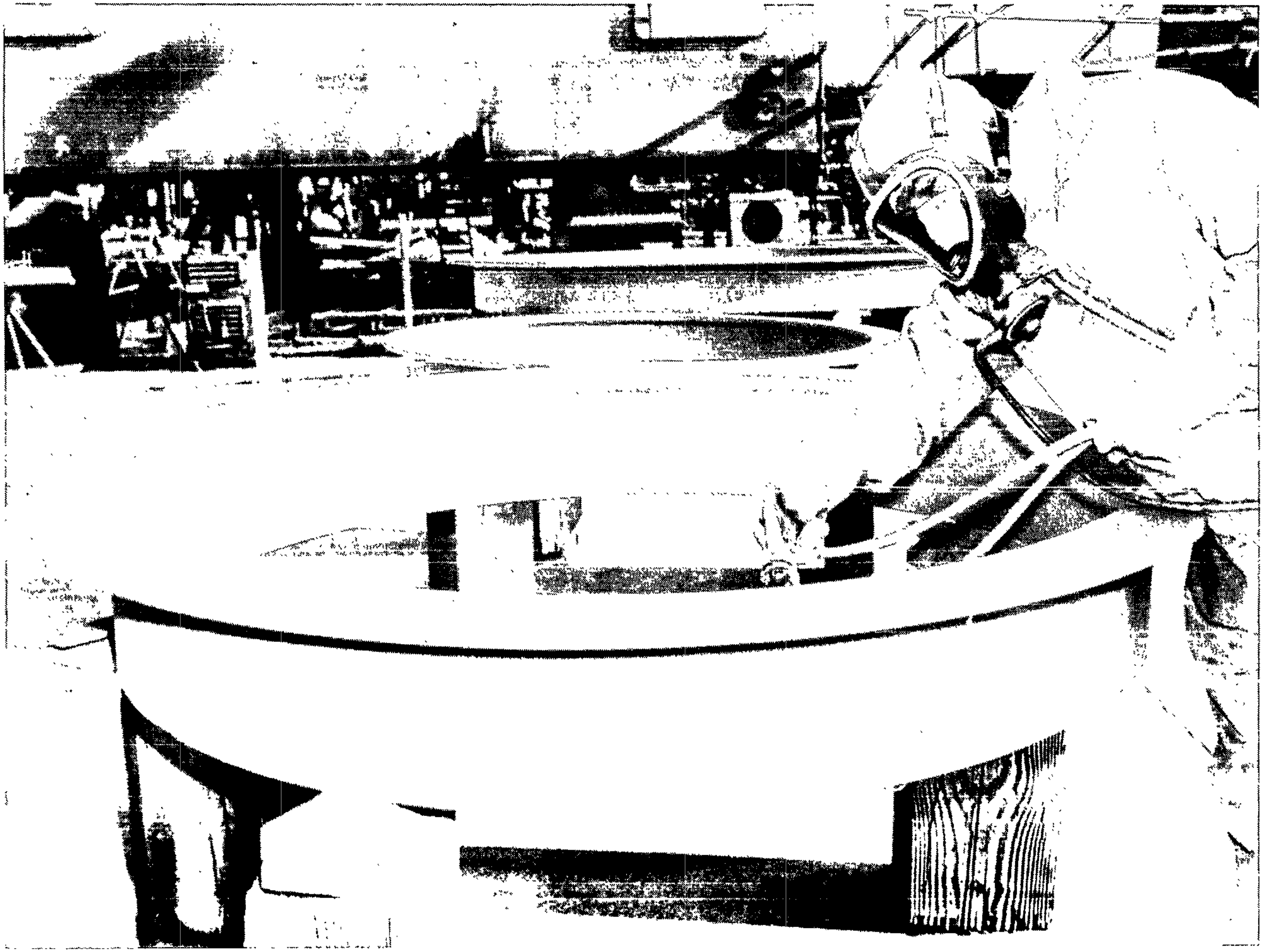

testex
PRESS-O-FILM
THICKNESS GAGE
THICKNESS FILM
TO CHECK SURFACE
PROFILE

PENTEST MAGNETIC GAGE TO CHECK COATING THICKNESS









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